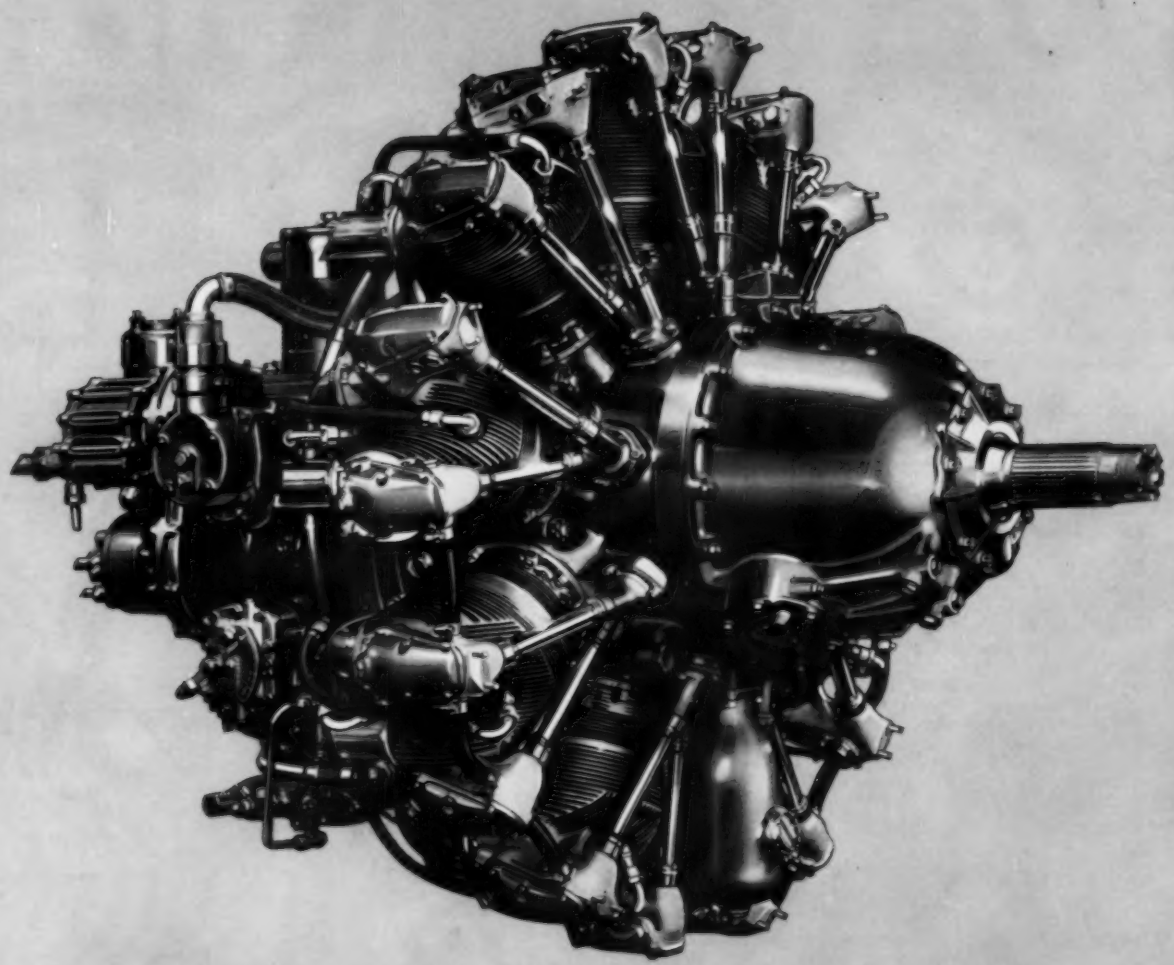
Flight
9 APRIL 1954

ONE SHILLING & SIXPENCE

FLIGHT

POWER UNITS OF THE WORLD

OFFICIAL ORGAN OF THE ROYAL AERO CLUB



ALVIS

LEONIDES

AERO ENGINES

Some useful information on

BICC Aircraft Cables

There are three main types of BICC Aircraft Cables, each appropriate to a specific temperature range. They have been developed in collaboration with the Royal Aircraft Establishment and conform fully to the appropriate Ministry of Supply or British Standard Specification.

Development work on aircraft cables is proceeding all the time in the BICC Research Laboratories. New insulating materials are continually being investigated, to provide more advanced types of cables to meet the future needs of aircraft designers.

For Working Temperatures -30° to 90°C

"PREN"

P.C.P. (polychloroprene) insulated.

Recommended for all general aircraft wiring except where the cable runs are situated in the vicinity of certain synthetic lubricating oils. The construction of these cables combines low weight and small dimensions with high abrasion resistance and flexibility. They are highly resistant to flame, and are designed to allow in emergency continued service for a short time after exposure to flame.

A number of constructions are available.

"PREN" Single-core and multicore cables. The multicore types have an overall glass braid.

"PRENAL" With aluminium conductors to reduce weight.

"PRENMET" Single and multicore cables with an overall braid of tinned copper wires.

"PRENSHEATH" Multicore cables with an overall P.C.P. sheath for use where high flexibility is required.

"UNIFLEXPREN" Highly flexible single-core cables with braided conductor for control-column wiring or similar applications.

Further information is contained in Publication No. 331.

For Working Temperatures -75° to 150°C

"GLASIL"

Silicone Rubber insulated.

Single-core flat twin and 3-core circular cables designed for use where temperatures exceed the safe limits for "Pren" cables—for instance, those encountered in installations associated with de-icing and cabin-heating equipment. Like "Pren" cables they are lightweight and resist moisture, most oils and flame.

Further information is contained in Publication No. 334.

For Working Temperatures -75° to 250°C

"GLASEF"

P.T.F.E. (polytetrafluoroethylene) insulated.

Single-core cables for use in the very high temperature regions of jet aircraft and in similar severe conditions where the resistance to heat and chemical stability of this insulant justifies its high cost. High-Energy Ignition Cables, with thicker insulation, are also supplied, for jet engine igniter leads. Other applications of P.T.F.E. insulation include thermocouple and compensating leads; radio connecting wires; radio frequency cables; and cable sleevings.

Further information is contained in Publication No. 319.

These are some of the more recent aircraft in which BICC Aircraft Wiring Cables have been used.

Civil

BRITANNIA

COMET

VISCOUNT

WESTLAND-SIKORSKI S51

Service

CANBERRA

FIREFLY

SEA HAWK

VALIANT

VULCAN

TECHNICAL ADVISORY SERVICE

BICC specialists are always available to help you select the appropriate cables for any particular working conditions. If you have any queries that lie outside the scope of the Publications listed, please do not hesitate to write for further technical information.

BI Callender's

The World's Largest Cable Manufacturers

SBAC

BRITISH INSULATED CALLENDER'S CABLES LIMITED, 21 BLOOMSBURY STREET, LONDON, W.C.1. MUSeum 1600

Springs, of all shapes and sizes, are needed to assist the movements of almost everything mechanical. Most of these are made by Terry's who have been Britain's leading spring and presswork specialists for nearly a century. During that time a host of problems have cropped up and been solved by Terry's research department so that today their experience is unique in this specialized field. If you are in difficulties over any question of springs or presswork rely on Terry's to spring to your assistance.

TERRY'S SPRINGS & PRESSWORK

Herbert Terry & Sons Ltd., Redditch, England

THE WORLD'S BEST GUNS

FOR LARGE SCALE AIRCRAFT, AUTOMOBILE AND INDUSTRIAL PRODUCTION

Deliveries stepped up by over 150%. Our 100% service will assist you to step up YOUR *production by 150% or more.*

The A.I.D. Model 2 and Model 7 guns fall right into line with the need of industry to effect increased production and saving of man-hours. These guns have been put to every known practical test, and their economical performance and mechanical perfection have made them the outstanding choice of great industrial organisations and Government Service Depts. all over the world.

AND THE WORLD'S BEST *SERVICE*

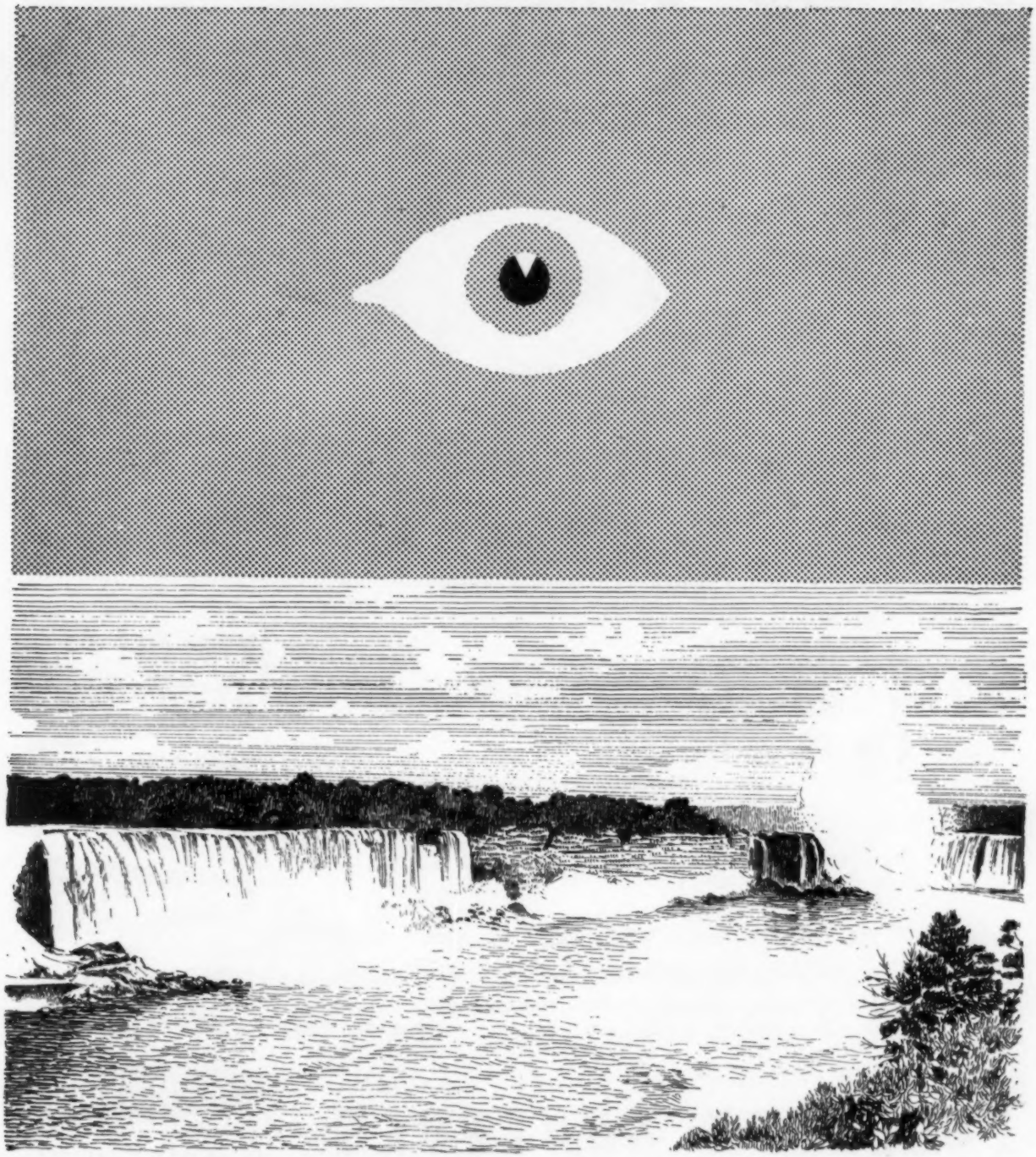
No service can excel the A.I.D. INSTANT RESERVE REPLACEMENT SERVICE which ensures 100 per cent. man-hour efficiency every hour of every day — New or reconditioned guns are exchanged instantly for your worn or damaged guns. A.I.D. not only supply guns, but EVERYTHING behind the gun. Whether your needs are large or small do not hesitate to request the services of our technical organisation.

AID

Overseas enquiries will receive prompt attention

CONTRACTORS TO THE WAR DEPARTMENT OF THE U.S.A. THE BRITISH AND COMMONWEALTH GOVERNMENTS

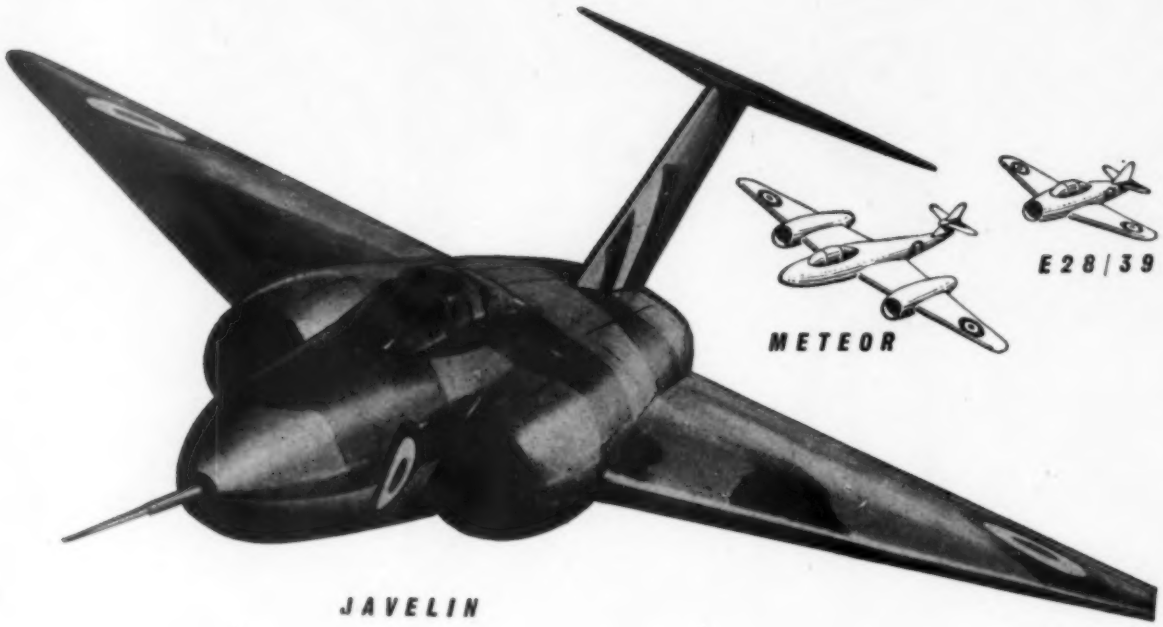
Sole Manufacturers: AIR INDUSTRIAL DEVELOPMENTS LIMITED, Aidspray Works, Shenstone, nr. Lichfield, Staffs, England. Phone: Shenstone 341/5. Grams: Aidspray, Shenstone. London, 28 South Molton Street, W.1. Phone: Mayfair 6318. Grams: Aidspray, Wesdo. Scottish Office, 90 Glasgow Road, Paisley. Phone: Paisley 3175. CANADA, 350 HILLCREST AVENUE, WILLOWDALE, nr. TORONTO, ONTARIO PHONE: BALDWIN 1/2677.



Niagara - Screenwash avoids driving eye-strain

KIGASS LIMITED 31, REGENT GROVE · ROYAL LEAMINGTON SPA · TELEPHONE 2480

ALWAYS LEADING



TELEFLEX CONTROLS were extensively used on both the **E28/39** and **METEOR**

We are proud of the fact that TELEFLEX CONTROLS are even more extensively used on the **JAVELIN**

THROTTLES · HIGH PRESSURE COCKS · LOW PRESSURE COCKS · FLAPS
AIR BRAKES · UNDERCARRIAGE · POWER CONTROL SELECTORS · TANK
JETTISON · BOMB JETTISON · HOOD JETTISON · SYNCHRONISING VALVES
RE-HEAT · RE-LIGHT · FUELLING VALVES · CABIN HEATING · ETC., ETC.

★ **E28/39**
WORLD'S FIRST
SUCCESSFUL JET AIRCRAFT

★ **METEOR**
WORLD'S FIRST
PRODUCTION TURBO-JET FIGHTER

★ **JAVELIN**
WORLD'S FIRST
QUANTITY PRODUCED DELTA JET FIGHTER

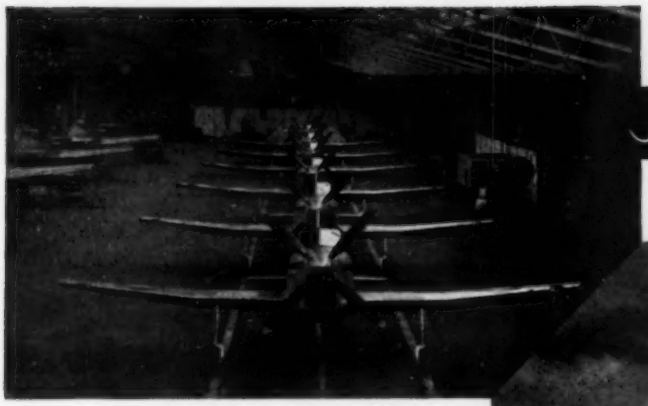
TELEFLEX CONTROLS

Used on all the Super Priority Aircraft in production for the R.A.F.

TELEPHONE: SEVEN KINGS 5771

TELEFLEX PRODUCTS LTD · CHADWELL HEATH · ESSEX

AUSTRALIA · BELGIUM · CANADA · DENMARK · FRANCE · GERMANY · HOLLAND · INDIA · ITALY · NEW ZEALAND
NORWAY · SOUTH AFRICA · SPAIN · SWEDEN · SWITZERLAND · U.S.A.

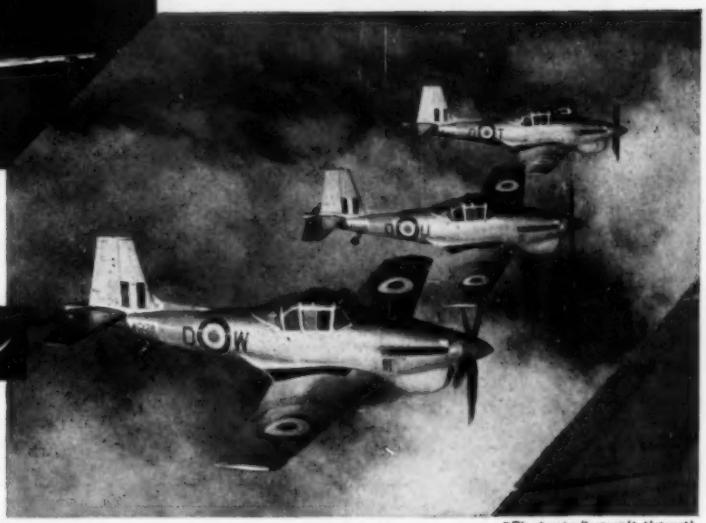


in production

and

in service

the



"The Aeroplane," copyright photograph

BALLIOL T. 2 advanced trainer

exhibits qualities that ensure a long and useful life at the lowest possible cost in money and manpower.

Designed for the utmost ease of servicing and repair, the Balliol is versatile in its uses and modest in its demands. Fuel consumption is low—no more than 40 gallons per hour at 200 knots at 10,000 feet—and utilization is high, due to the reduction in servicing times achieved by planned design. With a normal take-off run of 450 yards to clear a 50ft screen, the Balliol can operate with safety from small airfields in any part of the world.

BOULTON PAUL AIRCRAFT LTD

BPA

WOLVERHAMPTON, ENGLAND

SNAP JACKS

These high-thrust jacks require no external pressure system and are available as a replaceable cartridge or as a complete actuator for Canopy or Hatch jettison—drop and wing tank jettison—emergency cock operation—'one-shot' actuation. Movement of the lever releases stored air and snaps the jack open. Typical snap jacks are:

RES. 6. Initial Thrust 9,000 lb. Stroke 6". Weight 3½ lb.

RES. 2. Initial Thrust 3,500 lb. Stroke 1½". Weight 1 lb.

Hymatic

THE HYMATIC ENGINEERING CO. LIMITED · REDDITCH · WORCESTERSHIRE

146

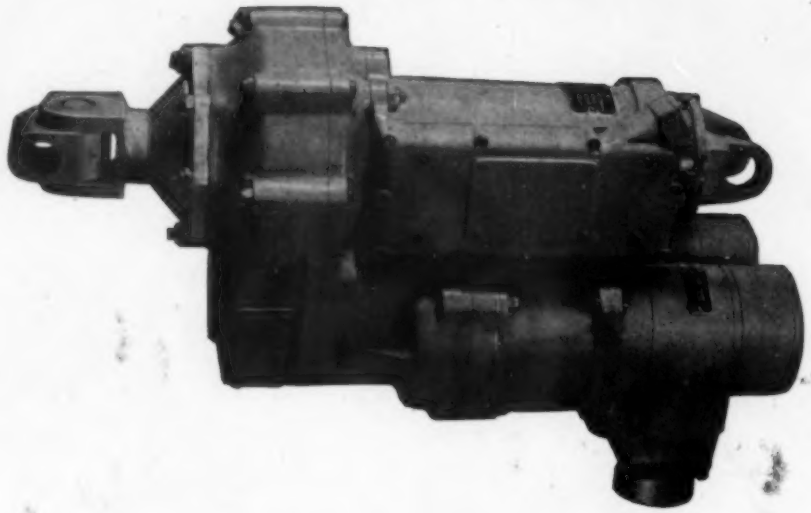
THE DOWNS AT DUNSTABLE *PHOTOGRAPH H. D. J. COLE, A.R.P.S., A.I.B.P., F.R.S.A.*

DESIGNED AND BUILT TO
BRITISH REQUIREMENTS

WESTLAND
S.51 HELICOPTERS

WESTLAND AIRCRAFT LIMITED · YEOVIL · ENGLAND

ACTUATORS



- **Comply with all prevailing specification requirements.**
- **Rugged mechanical construction**
- **Generous electrical design**
- **Built-in safety features**
- **Linear and rotary types for any application**

Illustrated is type 271, two-speed linear actuator. Maximum working load is 9,000 lbs. at high speed and 16,000 lbs. at low speed.

Motors are electrically independent, and magnetic brakes, clutch and position indication transmitter are fitted as standard.

by

'ENGLISH ELECTRIC'

AIRCRAFT EQUIPMENT DIVISION

Mechanical, Electrical and Hydraulic Accessories

THE ENGLISH ELECTRIC COMPANY LIMITED, QUEENS HOUSE, KINGSWAY, LONDON, W.C.2

Aircraft Equipment Division, Bradford

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

AE.4A

We Shape The Things to Come

We are proud to have been entrusted for many years with prototype, research and experimental work from Britain's leading aircraft and automobile manufacturers. We employ none but the finest craftsmen and are recognised as being amongst the foremost specialists in sheet metal manipulation in the country

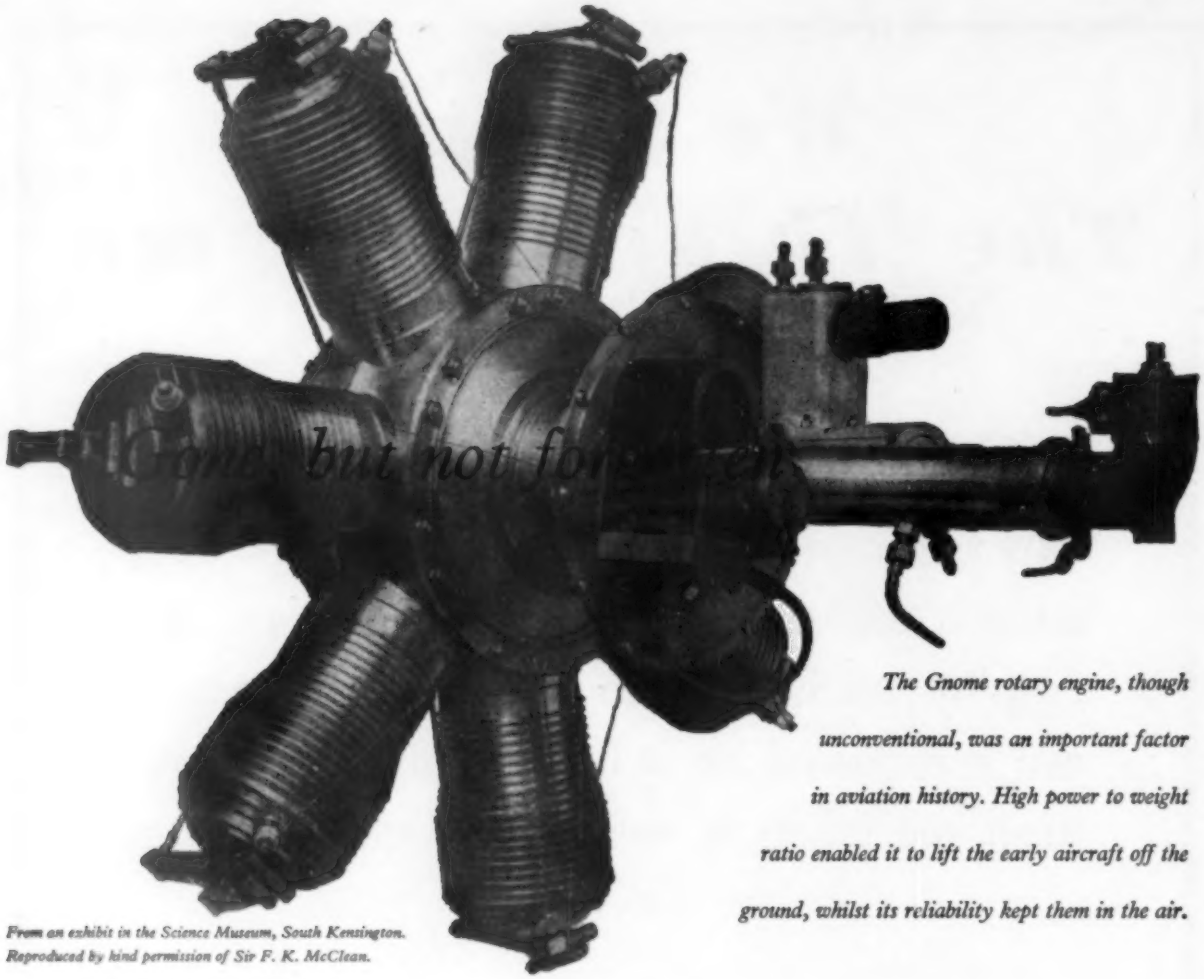
Experts in high-class shape panel work
Aircraft fabrication and assemblies

A.I.D. and A.R.B. APPROVED

ABBEY PANEL & SHEET METAL CO., LTD.

OLD CHURCH ROAD, LITTLE HEATH
COVENTRY

Telephone: COVENTRY 89461 (3 lines)



From an exhibit in the Science Museum, South Kensington. Reproduced by kind permission of Sir F. K. McClean.

The Gnome rotary engine, though unconventional, was an important factor in aviation history. High power to weight ratio enabled it to lift the early aircraft off the ground, whilst its reliability kept them in the air.

Forty-five years later structural weight is still a problem in aircraft design, because of its direct influence on payload. Of all modern developments in metal aircraft technique, none offers more advantages in weight saving than metal bonding. The use of synthetic resin adhesives makes possible assemblies weighing 25 per cent less, but which are stronger and more economical to produce. By eliminating rivets, local stress concentrations are avoided, a smoother exterior surface is provided, pressurizing is simplified and maintenance costs are greatly reduced.

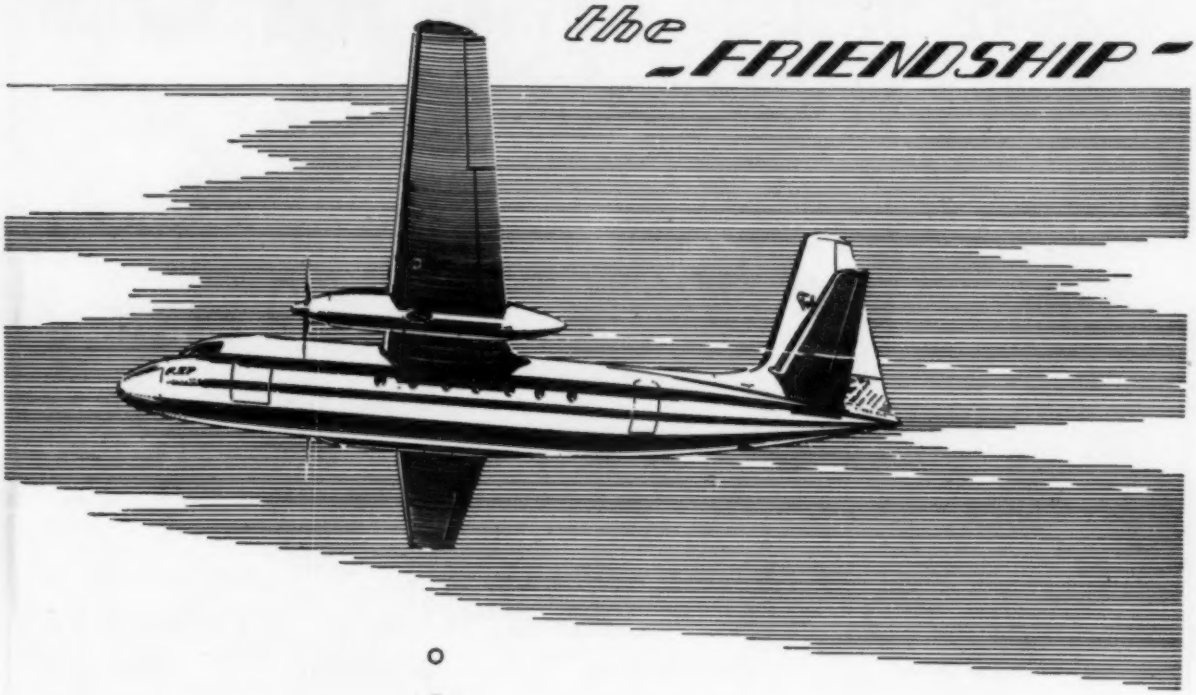
'Redux' BONDING PROCESS

'Redux' is a registered trade name

Aero Research Limited *A Ciba Company. Duxford, Cambridge. Telephone: Sawston 187*

®264-73

For short and medium range air traffic . . .



PROPELLER-TURBINES

☆

COMPETITIVE
TON-MILE COST

☆

ADAPTABLE PASSENGER/
CARGO ARRANGEMENTS

☆

BACKWARD FACING
SEATING ARRANGEMENT

☆

EASY MAINTENANCE
AND OVERHAUL

The Fokker F.27 "Friendship", 28-36 seat short and medium range air-liner with two Rolls-Royce "Dart" propeller turbines, has been specially designed to fill the gap between small feeder liners and 40-50 seat aircraft

ROYAL NETHERLANDS AIRCRAFT FACTORIES

AMSTERDAM — SCHIPHOL-Z

Tel. Addr. : FOKPLANES

Fokker

SCHOOL OF GAS TURBINE TECHNOLOGY

POWER JETS (RESEARCH & DEVELOPMENT) LTD.

During the last six years we have received pupils from over 200 firms, organisations and Government Departments. Three alone of the above have together sent us over 250 pupils. Our International Course held in May, 1953 included pupils from 17 different countries

Full particulars of Courses on application to:

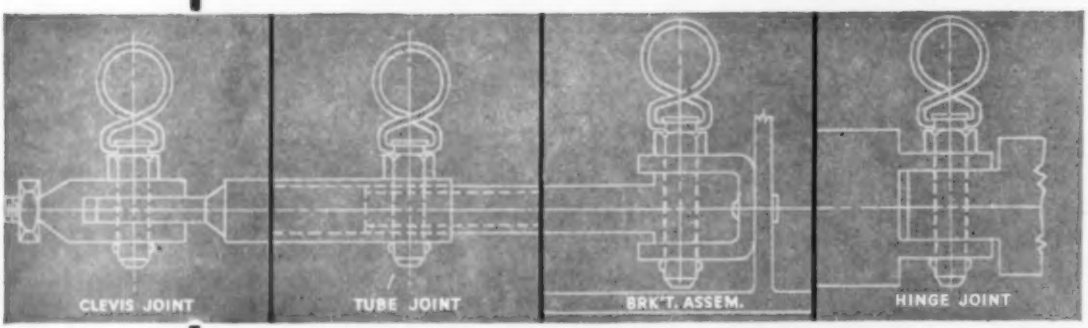
THE PRINCIPAL, SCHOOL OF GAS TURBINE TECHNOLOGY

Farnborough Place · Farnborough · Hampshire · England

Telephone: Farnborough 1300

Do you design for

SIMPLE, SPEEDY SERVICING?



A strong, positive lock in a second ! One push and the unique 'Pip-Pin' internal self-locking device gives a completely rigid grip—it releases just as simply—and only one hand is required for either operation. For such purposes as landing-gear downlock and scissor-attachment; conversion from passenger to freight; door and cowling hinges; fixture-points for goods stowage; control-rod assemblies; lifting-gear; bomb and other carriers; dip-sticks; and in fact any removable fixtures; etc. etc. 'Pip-Pins' are the answer to SIMPLE, SPEEDY SERVICING. The range of sizes is mechanically unlimited. Approved for use in aircraft under SDM No. 205 and ARB No. E 1130. Write for details of types available.

PiP-PiNS **For SPEED — ECONOMY — RELIABILITY**

AVIATION DEVELOPMENTS LTD

Kingsbourne House, 229-231, High Holborn, London, W.C.1. Tel: CHAncery 8601

B·A·P
We are in the 'hot' end of the
TURBINE INDUSTRIES
...and can take the "heat"
out of your problems
BURNLEY AIRCRAFT PRODUCTS LTD.
FULLEDGE WORKS · BURNLEY
LANCS., ENGLAND. Tel: Burnley 3121
SPECIALISTS IN THE
MANUFACTURE & REPAIR OF
FLAME TUBES, DISCHARGE
NOZZLES, EXHAUST SYSTEMS,
JET PIPES, INSULATING
BLANKETS, BELLOWS, FOR
AIRCRAFT, MARINE,
AUTOMOBILE OR
OTHER GAS TURBINE
DEVELOPMENTS.

Bowdenflex
Registered Trade Mark

HIGH PRESSURE HOSE UNITS

The Bowden Company, world famous for its Bowden wire mechanisms, also pioneered the development and manufacture of hose assemblies as fitted to most British aircraft engines

The extensive resources of the Bowden Company for the development, test and manufacture of hose assemblies for aircraft and aero engines are at the disposal of designers, manufacturers and operators

Series 10 and 50 Hose Assemblies
with swaged end fittings
Patented throughout the world

Series 30 Hose Assemblies
with reusable end fittings
World patents pending

Series 30 are repairable units, interchangeable with Series 10 and 50, and their use enables aircraft pipework to be serviced in the field

Bowden products are in universal use on land, sea and in the air

BOWDEN (Engineers) LTD
Design approved establishment—
M.o.S and A.R.B.

Willesden Junction, London, N.W.10
Phone: ELGar 4805
Cables: "Bowirelim, Norphone, London."
48-153

Drawn by James Bostock A.R.E., A.R.C.A.

"NO QUANTITY TOO SMALL"

Non-ferrous metals in the air . . . .

H. ROLLET & Co. Ltd.
6 CHESHAM PLACE
LONDON S.W.1.

LONDON · LIVERPOOL · BIRMINGHAM · MANCHESTER · LEEDS

Choose any runway

With the Decca 424 Airfield Control Radar *a change of runway need not mean any change in the setting up of the radar.* All runways — and their approaches — are covered as far as the radar is concerned.

The 424 has been ordered by the R.A.F. for landing jet aircraft and it is equally suitable for landing transports and airliners which it will pick up at 20-25 miles. It is simple to install and simple to operate and, most important, the cost is small enough to bring it within the budget of the smallest municipal airport. It is available in units for installation in permanent buildings; in an air transportable version which can be set up in a few hours; or as a completely self-contained mobile unit which can be working within minutes of driving onto an airfield.

And it is now in quantity production for early delivery.

DECCA 424 Radar

D.R.36 DECCA RADAR LIMITED, 1-3 Brixton Road, London, S.W.9

RELIABILITY

HYDRAULIC COMPONENTS

Airframe hours flown	1450
Aircraft in service	12
No. of hydraulic components	1000
Components confirmed faulty	2

LANDING GEAR

Total number of landings to date	22,572

An oleo has never failed on service causing a collapse.

Good-very good but not good enough. H.P.

...int those concerned with the ...L.W. system in the [redacted] ...nd landings of the [redacted] fleet ...ted the hydraulic system under ...ic components are overhauled ...lent to 2,400 flying hours, but ...components are the original ... were new.

Our objective is ABSOLUTE RELIABILITY pursued by - Continuous research - Careful design - Vigorous testing - and precise manufacture

★ The facts quoted are taken from an internal Service report of one of our customers

ELECTRO-HYDRAULICS LIMITED
WARRINGTON

FOR

EARLY

DELIVERY

FROM AVAILABLE MATERIAL

Contact

SALTER

ABOUT SPRINGS & PRESSWORK

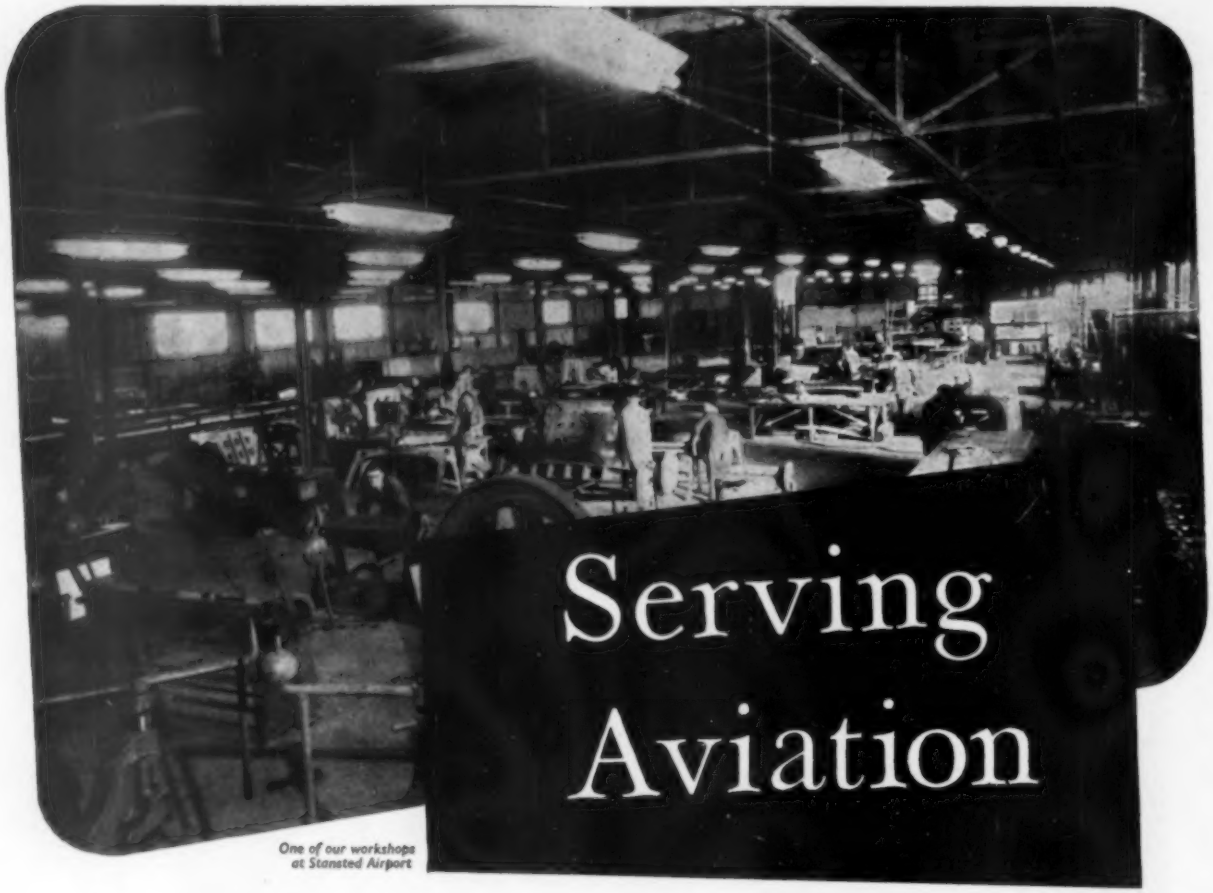
Write for free copy of the Salter Spring Handbook—it's full of useful information

GEO. SALTER & CO. LTD., WEST BROMWICH. Telephone: West Bromwich 1331 (8 lines)

LONDON Phone: Holborn 6046/7 MANCHESTER Phone: Blackfriars 8551 COVENTRY Phone: 3644

B.I.F. CASTLE BROMWICH STAND NO. D328

M-W.347



One of our workshops at Stansted Airport

APPROVED DESIGN AND DRAWING ORGANISATION

DESIGN AND/OR MANUFACTURE OF:—

Ground equipment.

Workshop and hangar equipment.

Jet power plant and engine stands and trolleys.

Jet engine slings, etc.

SUB CONTRACTING FACILITIES AVAILABLE INCLUDING:—

Airframe component manufacture or modification. All types machining — milling — shaping — drilling — turning. Sheet metal-work—heat treatment and welding.

A.I.D. AND A.R.B. APPROVED

Aviation Traders (ENGINEERING) LIMITED.

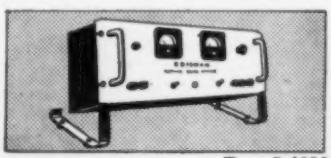
Telephone: AMBassador 2091 (5 lines)
Telegrams: "Aviatrade, Wesdo," London

15, GREAT CUMBERLAND PLACE, LONDON, W.1

PRELUDE TO POWER

For over 30 years Ediswan Engineers have been constructing standard and special rectifiers of widely varying capacity for all kinds of applications. The latest product of their experience and specialised knowledge is this Ediswan Rectifier for direct starting of jet engines under test. It is for operation on a 400 volt 3 phase, 50 cycle supply. The D.C. output is 600 amps at 90 volts which may be delivered for 30 seconds every 5 minutes. The Unit is protected by two thermostats connected in series and arranged to trip out a triple pole contactor in the event of over-heating. Four tappings on the output side are provided to give a choice of four outputs from a minimum of 77 volts.

The advice of Ediswan technicians is always at your disposal and we shall be glad to visit you and discuss your particular problems regarding Rectifiers for Jet engine starting.



Type R.1095

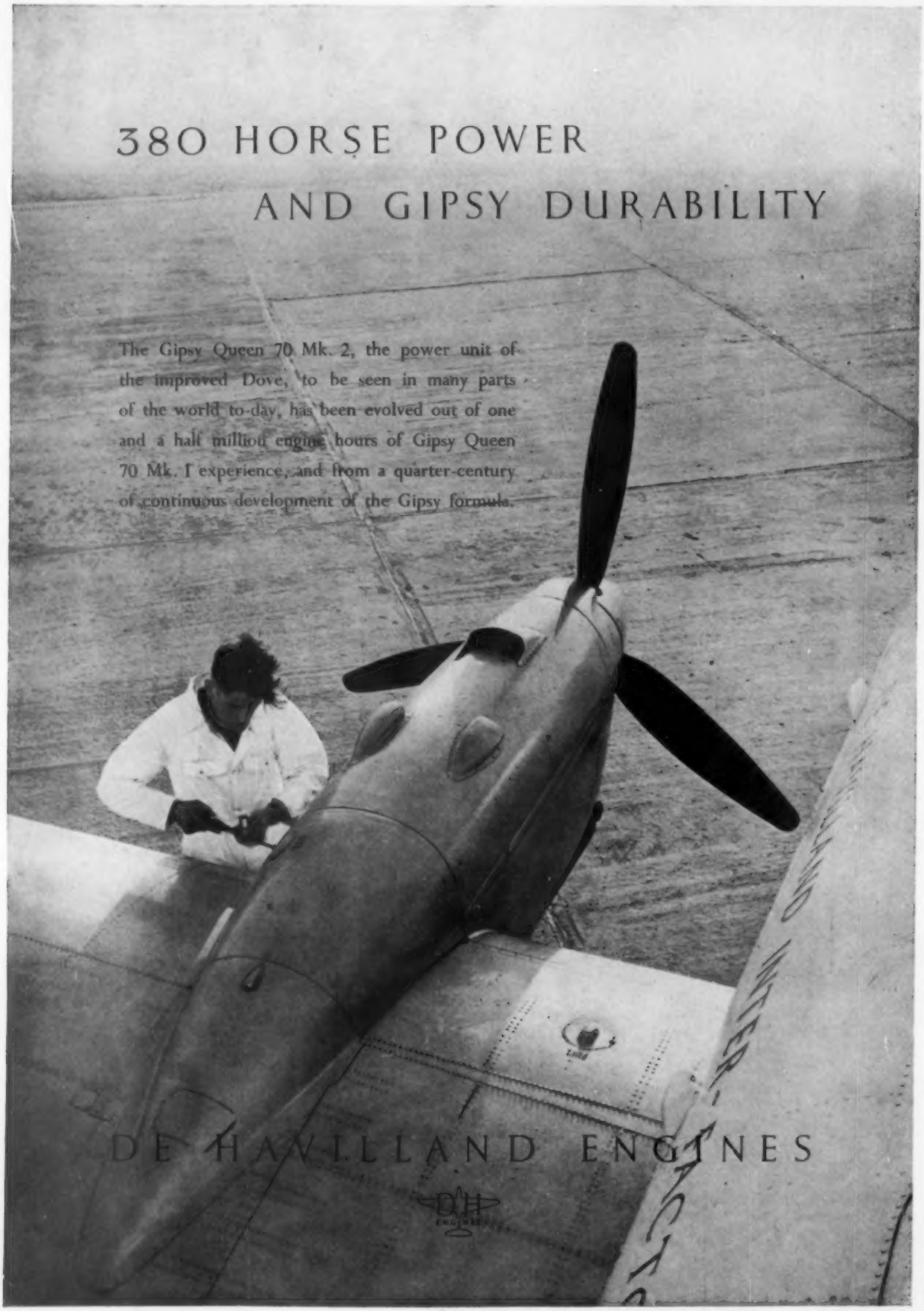
EDISWAN Stabilised Power Units are supplied to Aircraft Manufacturers for use with electronic test equipment.

TYPE R.1095 has an input of 200-250 volts, 40-100 c.p.s. and a high stability D.C. output of 120-250 volts at 0-50 mA and an unstabilised 6.3 volt A.C. 3 amp. heater supply. TYPE R.1103 with the same input, has a high stability D.C. output of 250-400 volts, adjustable in three ranges. Maximum load is 200 mA up to 350 volts and 150 mA from 350 volts to 400 volts. In addition two unstabilised 6.3 volt A.C. heater supplies are provided.

EDISWAN

SPECIAL RECTIFIERS

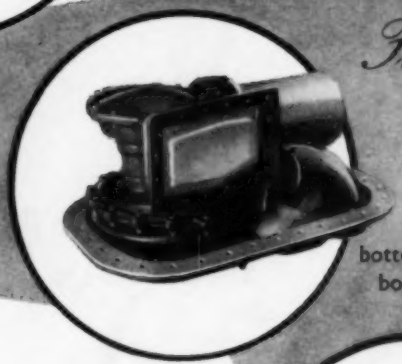
THE EDISON SWAN ELECTRIC CO. LTD., 155 Charing Cross Road, London, W.C.2. *Member of the A.E.I. Group of Companies* (T.139)


380 HORSE POWER
AND GIPSY DURABILITY
The Gipsy Queen 70 Mk. 2, the power unit of the improved Dove, to be seen in many parts of the world to-day, has been evolved out of one and a half million engine hours of Gipsy Queen 70 Mk. I experience, and from a quarter-century of continuous development of the Gipsy formula.
DE HAVILLAND ENGINES

recuperators

SPE

Fuel Booster Pumps and Fuel Line Equipment



bottom mounting booster pump

side mounting booster pump

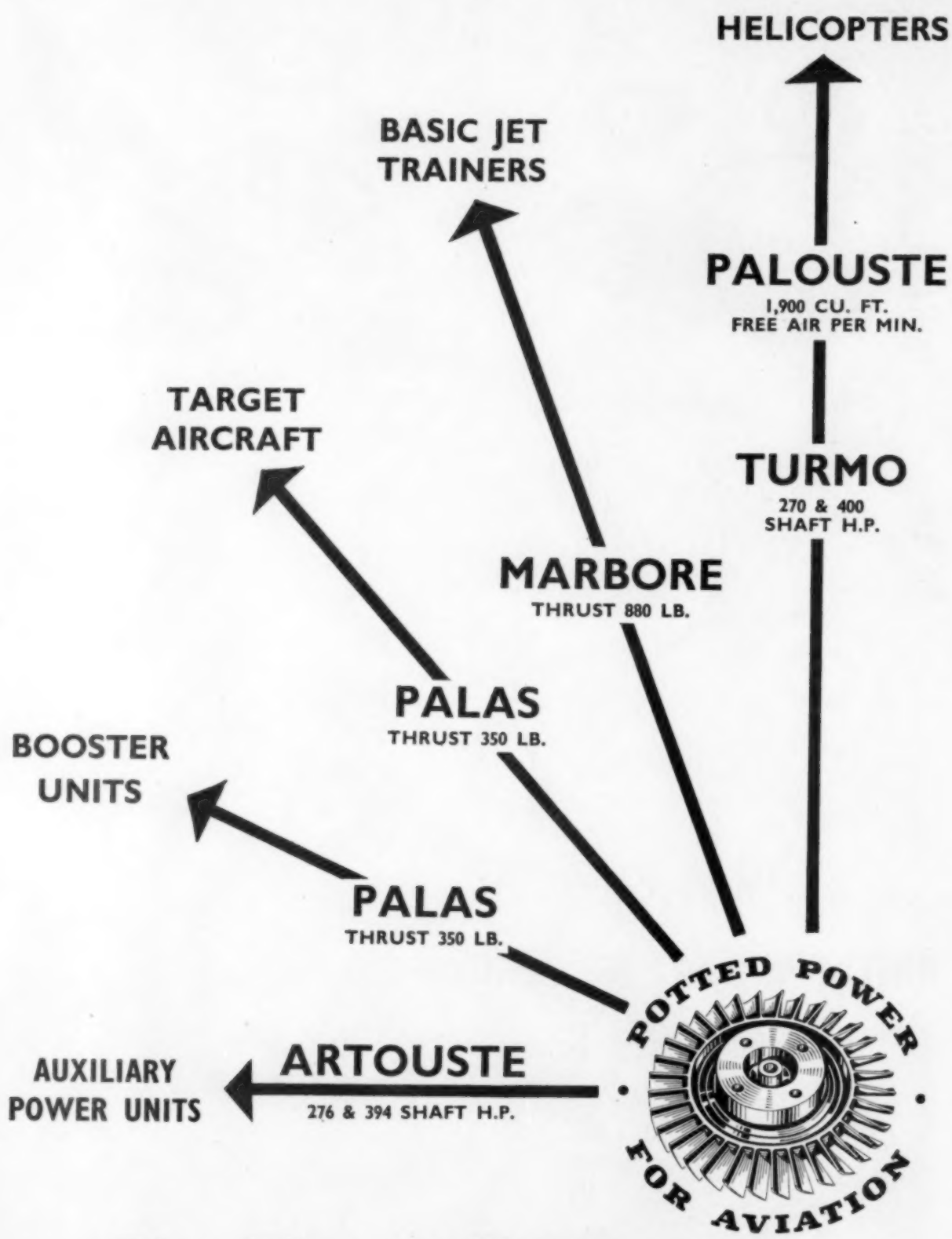
as supplied to

BRITAIN'S LEADING AIRCRAFT

IN USE THROUGHOUT THE WORLD

float valves

SELF-PRIMING PUMP & ENGINEERING CO. LTD., SLOUGH, BUCKS • *Telephone:* SLOUGH 23277



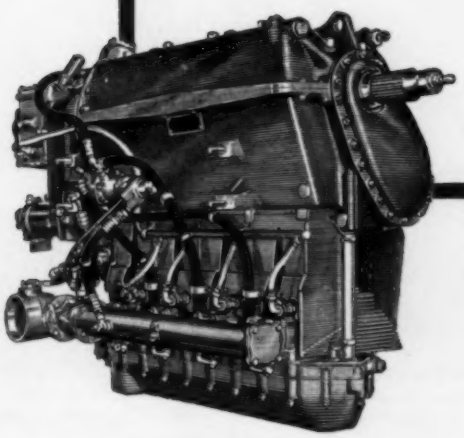
Blackburn-Turbomeca

43 Berkeley Square, London, W.1.

Saunders-Roe Skeeter

- **FULLY APPROVED BY THE MINISTRY OF SUPPLY AND AIR REGISTRATION BOARD.**
- **IMMEDIATE THROTTLE RESPONSE AND LOW FUEL CONSUMPTION.**
- **PRESSURE INJECTION DISTRIBUTES THE FUEL AND ITS LEAD CONTENT EQUALLY.**
- **NO ICING PROBLEMS AND SATISFACTORY STARTING AT –40°.**
- **NOW IN PRODUCTION FOR THE ROYAL AIR FORCE AND CIVIL OPERATORS.**

Auster B.4



Cirrus
BOMBARDIER
180 B.H.P.

Blackburn and General Aircraft Limited, Brough, E. Yorks

THE VIRTUES OF THE AVRO VULCAN

7. *Servicing Simplicity*

1. *Aerodynamic Simplicity.*
2. *Easy Landing.*
3. *Exceptional Safety.*
4. *Great Range.*
5. *High Altitude Flight.*
6. *High Speed Flight.*
7. *Servicing Simplicity.*
8. *Fighter-like Manœuvrability.*
9. *Large Carrying Capacity.*
10. *Great Development Potential.*

The Delta configuration of the Avro Vulcan achieves a remarkable reduction in auxiliary devices. No tailplane or flaps, no nose-flaps or slots, no high-lift mechanism of any sort. All servicing is done from underneath the aircraft and the absence of a high tailplane further simplifies maintenance in the most effective bomber in the world.

A. V. ROE & CO., LIMITED
Manchester

AVRO

Member of the Hawker Siddeley Group | Pioneer . . . and World Leader in Aviation

FLIGHT
and
AIRCRAFT ENGINEER

First Aeronautical Weekly in the World

Founded 1909

No. 2359 Vol. 65. FRIDAY, 9 APRIL 1954

EDITOR
MAURICE A. SMITH, D.F.C.

ASSISTANT EDITOR
H. F. KING, M.B.E.

ART EDITOR
JOHN YOXALL

Editorial, Advertising and Publishing Offices:

DORSET HOUSE,
STAMFORD STREET,
LONDON, S.E.1.

Telegrams, Flightpres, Sedist, London.
Telephone, Waterloo 3333 (60 lines).

Branch Offices:

COVENTRY
8-10, Corporation Street.
Telegrams, Autocar, Coventry.
Telephone, Coventry 5210.

BIRMINGHAM, 2
King Edward House,
New Street.
Telegrams, Autopress, Birmingham.
Telephone, Midland 7191 (7 lines).

MANCHESTER, 3
260, Deansgate.
Telegrams, Iliffe, Manchester.
Telephone, Blackfriars 4412 (3 lines).
Deansgate 3595 (2 lines).

GLASGOW, C.2
26b, Renfield Street.
Telegrams, Iliffe, Glasgow.
Telephone, Central 1265 (2 lines).

SUBSCRIPTION RATES
Home and Overseas: Twelve months £4 10s. U.S.A. and Canada, $14.00.

IN THIS ISSUE:

From All Quarters - - 422
Gannet, R.N. - - - - 423
Correspondence - - - 425
Here And There - - - 426
Civil Aviation - - - - 427
Service Aviation - - - 428
Busy at Baltimore - - 424
The Quest for Power - 429
Aero Engines, 1954 - - 445

Thoughts on Cranfield

THE value of the College of Aeronautics at Cranfield, and its place in the educational pattern of air technology, are today well recognized not only by the aircraft industry but also by responsible authorities in the wider field of general education. The selection of the Dean of the Royal Military College of Science, Dr. Sutton, and the chairman of the Bedfordshire County Council, Sir Frederick Mander, as speakers at the dinner of the Senior Common Room Society at Cranfield last week was therefore an appropriate one. Their appreciation of the overall objectives of Cranfield's work was clear; and one point is worthy of special emphasis.

Dr. Sutton made the distinction between the academic mind and what he called the executive mind: the former, he said, produced a 1st class Honours degree; the latter had the first-class creative ability to design an aircraft.

The College of Aeronautics is primarily concerned with the latter type. It should be remembered, however, that Cranfield exists not for the making of technicians able to apply the techniques evolved by others—all engineers must do that; it exists for the cultivation of minds that will evolve new techniques, i.e. technologists.

The prestige value of a university degree makes the university approach to higher technical standing more attractive—at present—than the diploma approach through Cranfield. Certainly if an aircraft apprentice or technical-college student is capable of obtaining a good Honours degree he ought to do so; the two-year Cranfield course would be more appropriate for the apprentice who has obtained an external degree and is following it up with a post-graduate course.

The post-graduate course in aeronautics at, for instance, Imperial College is well suited to men who have just completed a degree course there and are simply continuing their studies with the same professor and staff. Such men are likely to remain on the scientific side rather than transfer to technological and engineering careers.

Some confusion concerning Cranfield has arisen because of the various interpretations of the term "higher technological education". This description was originally invented to give a well-sounding title to a Governmental committee enquiring into the teaching of fundamental science and engineering in technical schools and colleges, for youths leaving school at the normal school-leaving age. It is a term which has proved too high-sounding for the curricula evolved. In this particular connection (resort to the phrase "super-higher technological education" mercifully not having been made) the effect has been to lower the standing of places like Cranfield.

Despite this confusion with both technical colleges and university colleges, it is a fact that Cranfield remains (certainly in this country and probably in the world) the only place where a man can obtain an all-round aeronautical engineering experience strongly based on fundamental studies in aeronautical science, and then undergo the mental training required by the creative aeronautical engineer.

An innovation of outstanding importance is the decision to develop the field of studies in aeronautical electricity and electronics. It is extremely desirable that aeronautical electrical engineers should be trained in the atmosphere of aeronautics, and it will be found that the effects on electrical engineering will ultimately be as profound as the effects on propulsion engineering of the genius of aeronautical propulsion engineers.

It is in the "atmosphere of aeronautics" found at Cranfield that the College's main strength lies. This concept of a true aviation community—a residential university located on Britain's third busiest civil aerodrome—is new; and perhaps it was this new thinking that caused the indifference and incomprehension of certain sections of industry and the older places of learning during the earlier years of the College's life. However, the worth of the letters "D.C.Ae." is now better established.

For the future, it would appear that there is room for a further expansion of activity, particularly in the fields of meteorology, the economics of production, and fuel technology. The aircraft industry has a great deal to gain from ensuring the continued development of Cranfield along these lines. The measure of the value of the College will be the degree to which time-saving in the development of creative capacity can be won. Only thus can we keep up with, let alone keep ahead of, developments elsewhere.

FROM ALL QUARTERS

NATO is Five

ON April 4th the North Atlantic Treaty Organization had been growing up for five years. President Eisenhower, himself a former Supreme Allied Commander, Europe, said: "Fourteen nations . . . are joined within it because each is determined to sustain its own independence. Dedicated to a common purpose, their strength is multiplied, their inexhaustible energies are pooled." The fourteen NATO Air Forces have steadily increased in strength and are incomparably more effective now than they have ever been; their organization and disposition have been outlined in several of our recent issues.

First Indian C-in-C. of I.A.F.

AIR MARSHAL S. MUKERJEE, O.B.E., was appointed C-in-C. of the Indian Air Force on April 1st, thus becoming the first Indian to hold the post. He takes over from Air Marshal G. E. Gibbs, C.I.E., C.B.E., M.C., who, on leaving, issued an order of the day in which he said, "I am convinced that the I.A.F. is firmly established and should go from strength to strength."

Air Marshal Mukerjee, who has recently taken a course at the Imperial Defence College in Britain, was among the first few Indian cadets admitted to Cranwell in the 1930s. He is 41. His appointment coincides with the 21st anniversary of the I.A.F., which was marked by an impressive ceremony near Delhi, at which the President, Dr. Rajendra Prasad, presented his Colours, "in recognition of the meritorious services rendered by the I.A.F. to the country." Addressing 1,500 officers and airmen, Dr. Prasad said, "Besides being the efficient sentinel of our skies, the I.A.F. never fails to render valuable help to the people in distress."

General Vandenberg

CHIEF OF STAFF of the U.S.A.F. since 1948 until his retirement last June, General Hoyt S. Vandenberg died last Friday, April 2nd, at the age of 55. A gifted officer, he left the Army War College in 1939 and came to England in 1942, subsequently accompanying the 12th Air Force, which he helped to organize, to North Africa. He was promoted brigadier-general in December 1942, and was appointed Chief of Staff of the North-West African Strategic Air Force. During this command he flew on numerous sorties. After being recalled to Washington to fill the post of Deputy Chief of the Air Staff, he headed a mission to Russia and attended the Quebec, Cairo and Teheran conferences.

In the crucial period before D-day he was commander of U.S.A.F.E.; and in August 1944 was appointed to command the 9th Air Force. After the war he became Director of Intelligence in the War Department, and then Director of Central Intelligence.

On the retirement of General Spaatz in 1948 General Vandenberg succeeded him as Chief of Staff of the Air Force and in that office strove for the strengthening of the U.S.A.F. after its post-war decline. He entered hospital in May 1952, but resumed work in the following August. Last December he was again taken seriously ill.

Cranfield S.C.R. Dinner

THIS year's dinner of the Senior Common Room Society at the College of Aeronautics, Cranfield, on March 31st, showed a healthy widening of the circle of guests.

The toast to the College and the Society was proposed by Dr. O. G. Sutton, C.B.E., D.Sc., F.R.S. A technological university, he said, was a mixture of university, technical college and research establishment—in equal proportions. Dr. Sutton went on to describe the differing approaches to engineering education (to which reference is made in our leading article).

The chairman of the Senior Common Room Society, Mr. A. H. Yates, B.Sc. (Eng.), A.F.R.Ae.S., replied. The College had grown, he reported; 150 students were now taking the two-year course, and 400 had attended specialized short courses during the past year. After listing additions to the staff, Mr. Yates referred to those who had left the College this session, and who were about to leave: these included Professor Young, of the Aerodynamics Department, who was moving to Queen Mary College, London, and the speaker himself.

The health of the guests was proposed by Sir Reginald Verdon Smith, J.P., D.C.L., M.A., who described himself as "a completely new boy" on the governing body of the College. He had been able to see, however, that much had been accomplished at Cranfield. The excellent reputation acquired was a tribute to Sir Roy Fedden's original committee; the present standards were high, and a great deal of goodwill had been generated in various institutions, including the Ministry of Education and the S.B.A.C.

Replying for the guests, Sir Frederick Mander, M.A., B.Sc., began by giving an enlightening account of his experiences at previous dinners. Referring to the College, the National Aeronautical Establishment and the A.R.A. wind-tunnel project, he went on to point out that Bedfordshire, home of "Pilgrim's Progress," was becoming also the home of aeronautical progress. For Sir Victor Goddard, principal of the College, and Mr. Yates, both of whom had identified themselves with the life of the county as a whole, the speaker had a high regard. "I watch the continued development of Cranfield," he concluded, "with interest and approval."

Colonel Rozanoff

ONE of the world's great test pilots, Colonel Constantin Rozanoff was killed at Melun-Villaroche last Saturday, April 3rd, while demonstrating a Mystère IVB in the presence of Mr. Duncan Sandys and a party of distinguished officials.

A colourful figure, he was born in Warsaw in 1905 and, after attending the Ecole Supérieure d'Aéronautique joined the French Air Force. He took up test flying in 1935 and on the outbreak of war assumed command of a fighter squadron. By the end of the war he had been awarded the Croix de Guerre and had been three times mentioned in despatches. After a period at Mont de Marsan he became chief test pilot to the Dassault Company.

With Aeronautical Flavour

THE flying Services and the aircraft industry were well represented at the Livery Dinner of the Worshipful Company of Coach Makers and Coach Harness Makers, held at the Mansion House, London, on March 22nd. The guests of honour were the French Ambassador, M. Massigli, and Mme. Massigli, and the R.A.F. was represented by Marshal of the Royal Air Force Lord Trenchard and Air Marshal Sir Dermot Boyle, A.O.C-in-C. Fighter Command.

The Senior Warden, Mr. W. J. Connolly, proposed the toast of the Lord Mayor, Sheriffs and Corporation of the City of London, and the Lord Mayor, Sir Noël V. Bowater, replied. In the absence of Sir Miles Thomas, Sir Anthony Hawke, the Common Serjeant, proposed the toast of the Company, and Mr. Roland Dangerfield replied. These speeches were followed by others of an equally high standard, made in turn by Sir Frederick Handley Page and Admiral of the Fleet Sir Rhoderick McGrigor.

Bill Waterton Hands Over

IN succession to S/L. W. A. Waterton, G.M., A.F.C. and bar, who is leaving, W/C. R. F. Martin, D.F.C. and bar, A.F.C., has been appointed chief test pilot to the Gloster Aircraft Co., Ltd. A statement from the Hawker Siddeley Group runs: "Bill Waterton has been with us as chief test pilot for seven years and is leaving us now with our very best wishes. During his tenure as chief test pilot he has been in control of the Meteor during its long and successful service in the R.A.F. and in ten countries overseas. He has flown three prototypes, the Gloster E.1/44, the Avro Canada CF-100, and the Javelin. To date, he has done most of the development flying on the Javelin since its first flight as a prototype, and in 1952 he was awarded the George Medal 'for an act of courage beyond the call of duty,' when he crash-landed a prototype in such a way that valuable records were preserved."

W/C. "Dickie" Martin passed out at Cranwell in 1939 and was posted to No. 73 Fighter Squadron at Digby. He was in France with the A.A.S.F. at the outbreak of the late war, won his first D.F.C., and returned to England for posting to a Fighter O.T.U. In 1941 he went to the Middle East, where he served with several fighter squadrons and won the bar to his D.F.C. Late in the war he was transferred to Transport Command and finished up in India and China. In 1945 he went to the Empire Test Pilots' School, afterwards becoming a flight commander at the R.A.E. During this period he was awarded his A.F.C. He returned to the E.T.P.S. as an instructor and then attended No. 2 course at the R.A.F. Flying College, Manby. He is a private owner and acts as pilot to the Shuttleworth Collection of vintage aircraft.

W/C. Martin.

This summer, with W/C. Martin in charge of the Gloster test team, Glosters hope to complete the flight trials of the Javelin.

A-S Faireys Handed Over for Intensive Operational Trials

"FLIGHT" Photographs

GANNET, R.N.

AT a ceremony at R.N.A.S., Ford, Sussex, on Monday last, the Navy's first unit of Fairey Gannet anti-submarine aircraft—703X Flight—made its first public appearance. In true Naval tradition, these four Gannets contrived to appear smart and efficient, if not precisely handsome, for this special occasion, which comprised the handing over of their log-books by Sir Richard Fairey, M.B.E., to Lt. Cdr. F. E. Cowtan, commanding officer of the flight.

The formation of 703X Flight last month followed an extensive series of flight tests and carrier tests—in fact, successful completion of all acceptance trials by the Gannet—and marks the beginning of the quantity-delivery flow of these machines from the production line. The Gannet, the first Naval aircraft to be designed solely for anti-submarine work, will gradually replace Avengers, Skyraiders and Fireflies at present in service with the Fleet.

At the handing-over ceremony, Vice-Admiral Sir John Eccles, K.C.V.O., C.B., C.B.E., Flag Officer Air (Home), said that the coming into service of the first Gannet flight was not only a very important one to the Navy and the Fleet Air Arm, but was, in general, a most welcome and heartening occasion. As it was up to the older ones to set a good example to the younger and less experienced types, the Fairey Swordfish was present on this occasion also. He hoped that the brash new Gannet would follow in the slipstream of the "Stringbag" and become as well known and affectionately regarded as that "benevolent and tolerant mistress of many pilots, observers and air gunners" had been.

Before passing over the log-books to Lt. Cdr. Cowtan, Sir Richard Fairey remarked that it was over 41 years since he first handed over an aircraft to the Royal Navy—surprising as it might seem, this machine had folding wings, and radio. "I have been at it ever since then," he continued, "progress has been by gradual steps, and all this experience has gone into the Gannet." Sir Richard concluded by hoping that the Gannet would serve the Navy as well as her predecessors had, and said that, although his company would never make aircraft quite worthy of those who flew them, machines such as the Gannet were of the best possible quality.

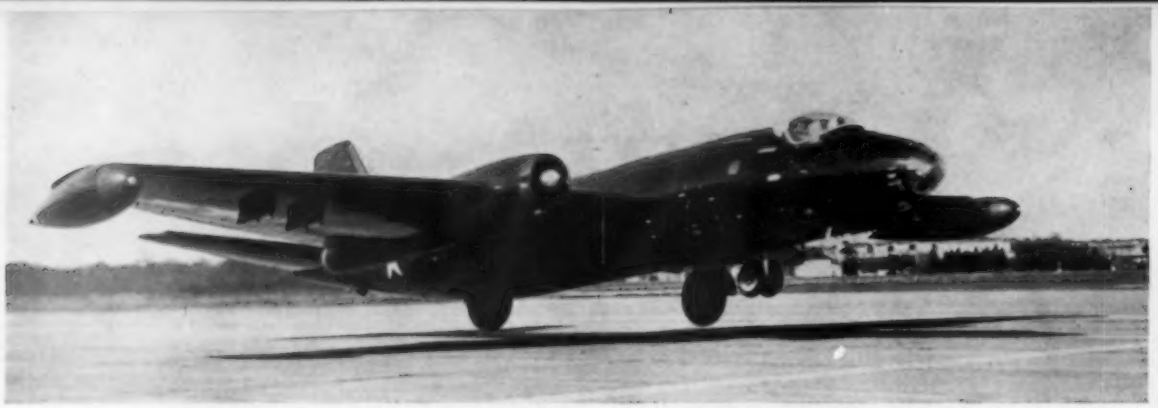
After the log-books had been accepted by Lt. Cdr. Cowtan, the four Gannets, preceded by the lone Swordfish, NF 389, taxied out to begin a short flight demonstration. In the presence of Vice-Admiral Eccles, Sir Richard Fairey, Capt. L. E. D. Walthall (Captain of R.N.A.S. Ford) and other representatives of the Service and the Fairey company, the aircraft then flew past, led by the Swordfish. A low run in line abreast by the Gannets was followed by individual runs showing various configurations (one airscrew feathered, "dustbin" down; wheels and hook down; bomb doors open; and everything up). A second formation run completed the demonstration, after which the Gannets taxied in past the control tower, folding their wings protectively over their canopies. The present flying programme of 703X Flight comprises intensive-flying trials.

It may be recalled that the Gannet began life as Ministry of Supply specification GR 17/45. The Fairey company received a prototype contract on August 12th, 1946, and on September 19th, 1949, the Fairey GR 17/45 was flown for the first time by the firm's chief test pilot at Aldermaston. This aircraft in fact resembled the present Gannet only slightly.

During the course of the design process, the Naval requirements altered, as a result of developments in armament, radar and operational techniques. A three-seat version with different armament (and other changes) was asked for. These changes were incorporated in the third prototype, which flew on May 10th, 1951. Development and test flying had continued meanwhile, and on carrier trials the three GR 17/45 prototypes made well over 250 deck landings. In October 1953 this work culminated in the first production Gannet successfully completing an intensive series of deck landings, many of these in poor weather and at night.

The Fairey system of "envelope jigging" is used extensively and successfully on the super-priority Gannet. At present the machines are built at the Hayes factory, transferred to Northolt for assembly, and finally flown to White Waltham for collection by the Navy. In due course, the greater part of the production will take place at Stockport, detail parts being made at Hamble.

Ceremony at Ford: Below, Sir Richard Fairey is shown handing over the Gannet log-books to Lt. Cdr. F. E. Cowtan and being introduced to 703X Flight aircrews. The formation at the top of the page shows that the pilots are thoroughly familiar with their new aircraft.



An RB-57 high-altitude reconnaissance aircraft for the U.S.A.F. gets off smartly from the Martin airport. Finish is shiny black, with red lettering

BUSY AT BALTIMORE

Martin Production of Canberras and Other Fine Aircraft

FROM the Editor, whose world tour is now well under way, comes news gleaned during his visit to the Glenn L. Martin plant at Baltimore, Maryland.

Many readers will recall the articles dealing with the Martin B-57 Canberra which have already appeared in *Flight*—particularly those of October 2nd, 1953, and January 15th last. At present the company are producing the B-57A light bomber and the RB-57 reconnaissance variant. The former resembles in essentials our British-built English Electric Canberra bombers, but the power-plants are Wright- or Buick-built J65 Sapphires, and there has been a considerable amount of detailed revision, including the installation of a rotating weapons bay.

The two Canberra variants are being assembled at a very creditable rate in the Government-owned, Martin-managed, No. 2 plant at Baltimore, and the Editor was extremely impressed by the output. This is now building up to a peak and could quickly be expanded to far greater proportions. The automobile industry is heavily involved, Buick making the engines, Kaiser the wings, and Hudson the tail. Martins are already turning out over 60 per cent of the wings and will eventually take over wing manufacture entirely.

The co-operation existing between English Electric and Martin is a model of its kind, and the Editor instances a nice example. When aileron production ran into trouble, causing a bottleneck, English Electric immediately despatched some ailerons which were straightaway fitted to Martin machines. As was described in our issue of January 15th, aerodynamic modifications, including the complete sealing of gaps in the tailplane and elevator, have postponed the onset of buffeting and Mach turbulence and the improvements are now standard on Martin production aircraft.

Arrayed for final ground-testing are nine RB-57s. In the background are P5M Marlin flying-boats for the U.S.N., the rear pair having T-tails

The next Canberra variant to be built at Baltimore will be the B-57B Intruder, which, according to American reports, will have an armament of 20-mm guns and an assortment of other offensive weapons. The crew of two will sit in tandem beneath a long canopy, somewhat similar to that of the Meteor night fighter. This canopy, incidentally, was test-flown on an early British-built Canberra and was illustrated in our issue of October 2nd, 1953. Another innovation on the Intruder will be fuselage air brakes, in addition to the existing finger-type brakes on the wings. The first Intruder has just been completed.

The Editor was also very impressed by the production of B-61 Matador subsonic pilotless bombers. These are powered by the Allison J33 turbojet and are becoming operational in Germany. A remarkable form of integrally stiffened sandwich-type construction is used, and now that the factory concerned is completely tooled for production, Matadors are coming off the lines at a great rate (picture April 3rd, 1953, page 426). The main constructional sandwich honeycomb is supplied as a slab from a specialist outside-contractor; this is then cut up with band-saws after which the skin is, colloquially speaking, "wrapped round, stuck on and baked." The number of parts is kept to a minimum and assembly man-hours are very low.

Work on the newest version of the P5M Marlin patrol flying-boat is very active. Powered, like earlier Marlins, by two Wright Turbo-Compounds, the new boat has revised front-hull lines and a high T-tail, the latter requiring some 20 per cent less area.

Martin have high hopes for the new multi-jet XP6M flying-boat—a very fast patrol bomber and mine-layer, unofficially reported to have four engines, podded above the wing. With Convair, they have developed special handling gear for such aircraft, and they foresee complete water-based task forces, both for patrol and transport, and for refuelling submarines at sea. They consider that flying boats could be developed to have a performance equal to, or better than, that of the B-52 land-based bomber; and they would be some 20 per cent lighter than a land-based design for the same job. Both the Marlin and the XP6M (which has been given the name "Seamaster") have very advanced hydrodynamic characteristics, with long thin hulls.

FOR WHOM THE BELL TOILS

TEN helicopter test pilots stationed at Bell Aircraft Corporation's various installations around Fort Worth, Texas, are claimed to have made 7,569 test flights during 1953 without a single instance of damage to aircraft or persons. Total flight-time was 2,074 hours 8 minutes. In 1952, these pilots made 6,631 flights, also without mishap.

At the present time, Bell production centres principally on the Model 47 three-seat machine, which is in service with the U.S.A.F. as the H-13 and with civil operators in some 30 countries as well as in the United States. The model 48, an 8-10 seater, is also in production for the U.S.A.F., and the new tandem rotor HSL-1 anti-submarine machine has just been put into production; the first was delivered to the Navy in January.

Altogether during 1953, state the company, 5,619 production test flights were made, totalling 1,151 hr 48 min; 1,095 experimental test flights occupied 565 hr 40 min; and 855 demonstration flights accounted for 386 hr 40 min. At the Texas division, 1,157 training flights took place, totalling 775 hr 26 min.

CORRESPONDENCE

The Editor of "Flight" does not hold himself responsible for the views expressed by correspondents in these columns; the names and addresses of the writers, not necessarily for publication, must in all cases accompany letters.

Over-powered Pups

From Lord Balfour of Inchrye, P.C., M.C.

I READ with nostalgic pleasure the recent letters about the 1914-18 Sopwith Pup. These old aircraft possess a fascination for those who flew and who tended them.

Are your readers aware that in 1917 a few Pups were gloriously (even if inefficiently) over-engined by being with 100 h.p. "Mono" Gnôme motors?

Each flight commander at Gosport School of Special Flying under the late Col. Smith-Barry had one allotted to him as a private plaything to let off steam on. One day Major Bell-Irving, M.C., and I fetched two from Farnborough. The "clock" could be got to 100 m.p.h. with nose held down, hedge hopping. On arrival at Gosport, Bell-Irving did a climbing turn, stalled and spun, badly crashing his legs and ankles.

Another over-engined aircraft was a Bristol Scout, with the 80 Gnôme replaced by a 110 h.p. Clerget, which I flew in the old Test Flight, pre-runner of Martlesham, in August 1916.

Our fleet included a side-by-side Clerget Bristol and a "one off" Clerget Avro two-seater fighter, built on the lines of the 1½-strutter. She was a brute to handle and finally killed her pilot, the well-known scientist Captain Garnett, who spun her in from 2,000ft.

The two nicest aircraft to fly then were the Bristol monoplane and a little 80 le Rhône Vickers pusher scout built to the same specification as the F.E.8 pusher scout. I wonder how many of your readers remember the A.W. quadruplane we had?

In early 1916 at Gosport I looked in the log-book of an 80 Gnôme-Grahame-White Morane I flew and found it was Hamel's old pre-war aeroplane on which he gave his Windsor Castle display.

London, S.W.1. BALFOUR OF INCHRYE.

Reserve School Recollections

I READ with interest the article [March 19th] written by Mr. C. Nepean Bishop dealing with "Reserve School Recollections," and I feel that one interesting piece of news was left out, e.g., the time when a Magister was stolen from Carlisle by two escaped German prisoners-of-war. At that time I was the staff officer at Headquarters, No. 51 Group, who had to deal with the subject; and it would be interesting to hear, from the School's point of view, their version of the incident. At the time it caused a certain amount of consternation, but, upon reflection, was extremely amusing.

Dealing with another subject, before the war Air Ministry gave a certain number of decorations to the then Reserve Flying Schools, but post-war nothing has come their way at all. It would be a pleasant gesture on the part of the Royal Air Force to give a number of decorations to the members of the staffs of these schools as a token of appreciation for the hard work carried out over the post-war years.

Sutton Coldfield, Warwickshire. AVIATOR.

Royal Air Force Club Membership

From A. Cdre. W. P. G. Pretty, C.B.E.

WITH reference to the letter from the Officer Commanding No. 601 (County of London) Squadron contained in your issue dated March 26th I am pleased to inform you that at the annual general meeting of the Royal Air Force Club which was held on Thursday, March 25th, it was agreed that serving officers of the Royal Auxiliary Air Force should be offered membership on the same terms and at the same rates of subscription as serving officers of the Royal Air Force.

This decision is effective from April 1st, and the subscription rates are being amended accordingly.

London, W.1. WALTER P. G. PRETTY,
Chairman, Royal Air Force Club.

I SYMPATHIZE with S/L. McCarthy-Jones [March 26th] in his disappointment that the "concessions" in subscription rates to the R.A.F. Club do not apply to R.Aux.A.F. officers. But I have an even greater fellow-feeling for the club secretary, who has probably been bound rigid by the complaints from different sections of his members since the new rates were introduced.

The more a club varies its subscriptions in an effort to attract members the more discontent there will be—and there is a certain amount of justification for all the grouses. One can even state a reasonable case for or against the customary difference in town and country membership rates. Country members can contend that, as they cannot use the facilities of a club as often as town members, they should not be called upon to pay the same subscription. Town members can say (and *do* say) that it is their support which swells the trading profits without which the club could not carry on, so why should they be penalized by having to pay a higher subscription?

As someone once said—you can't please everybody.

London, W.1. G. A. THORNE,
Secretary, The Pathfinder Club.

DE HAVILLAND RESULTS

RESULTS of 1953 (to September 30th) trading by the de Havilland companies were announced last week. Net surplus of the group, after providing for all changes except U.K. and Dominion taxation, was £2,639,193 (1952, £1,678,043). Taxation absorbs £1,799,112 (£1,053,175), leaving £840,081 (£624,868).

The Board has decided to recommend a dividend of 7½ per cent on £4,385,459 Ordinary stock, and at a quarter of that rate on the Ordinary stock issued in June last year.

VICKERS TEST-PILOT APPOINTMENT

NOW on the test-pilot staff of Vickers-Armstrongs Weybridge works is S/L. B. G. Aston, D.F.C. His R.A.F. career dates from the time when he was granted a short-service commission in 1939, his first operational flying being with No. 500 Sqn. at Detling, Kent, in 1940. He was subsequently posted to No. 280 Sqn., and later flew Spitfires and Mosquitoes on long-range photographic sorties. It was during one of these operations, in January 1944, that he was taken prisoner after his flash-bombs had burst inside the Mosquito at 25,000ft. On return to England in 1945 he resumed duty with P.R.U. units, and on demobilization in 1946 he joined Scottish Airlines as a captain. A year later he returned to the Service with a permanent commission, and passed the day fighter leader course on Meteors at C.F.E. From 1950 until last year he was at Boscombe Down, and during this period became the first R.A.F. officer to fly a jet aircraft—a "hooked" Meteor 3—from a carrier. At the A. and A.E.E., in September 1951, he took part in the initial handling trials of the Valiant. In S/L. Aston's log-book are 4,000 hours on 127 different types.

S/L. Aston.

FORTHCOMING EVENTS

April 9. Helicopter Association: "Navigation of Helicopters," by D. M. Davies.
April 10-13. Air display and show, Rhine-Main Airport, Frankfurt.
April 10. British Interplanetary Society (Midlands branch): Film show, "Destination Moon."
April 10. British Interplanetary Society (Provisional Yorkshire branch): "Life on Other Planets," by G. Hollis.
April 13. R.Ae.S. Section Lecture: "Aspects of Modern Aircraft Materials," by Dr. H. Sutton, C.B.E., F.R.Ae.S.
April 14. Royal United Service Institution: "Air Power and the Future of War," by Marshal of the R.A.F. Sir John Slessor, G.C.B., D.S.O., M.C.
April 22. Guild of Air Pilots and Air Navigators: A. G. M.
April 22. R.Ae.S. Main Lecture: "Diesel Compound Engines," by E. E. Chatterton, B.Sc., A.M.I.Mech.E., F.R.Ae.S.
April 24. British Interplanetary Society (North-west branch): Film show.
April 24. British Interplanetary Society (Provisional Western branch): Exhibition and film show.
April 27. R.Ae.S. Section Lecture: "Aerodynamic and Aeroelastic Characteristics of the Crescent Wing," by G. H. Lee, B.Sc., D.I.C., A.R.C.S., F.R.Ae.S.
May 6. R.Ae.C.: Annual general meeting.
May 9-16. Saar Aero Club: International gliding contest and rally.

R.Ae.S. Branch Fixtures (to April 23).—April 13, *Belfast*, annual general meeting; April 14, *Glasgow*, annual general meeting; *Hatfield*, discussion evening; *Preston*, annual general meeting and film show. April 15, *Gloucester and Cheltenham*, annual general meeting.
April 23, *Hatfield*, annual dinner.

HERE AND THERE

Ships' Bells

EIGHT Bell HSL-1 anti-submarine helicopters will soon be shipped to the United Kingdom under the terms of the Mutual Defence Assistance Programme. The HSL-1 is a ship-borne twin-rotor machine, with a Pratt and Whitney R-2800 engine.

Demons Grounded

FOLLOWING three accidents in a fortnight, the U.S. Navy has temporarily grounded McDonnell F3H-1N Demon fighters. One aircraft of this type is reported to have exploded in the air (the pilot baled out safely); a second made a successful landing after an engine failure; and the third caught fire in the tail section and crashed after the pilot had baled out safely.

Britain's Aircraft Industry

OFFICIAL figures show that firms producing airframes, engines, undercarriages and airscrews now employ a total labour force of 230,000. This estimate does not include companies working on sub-contracts or those making parts and accessories, and the figure quoted can be taken to represent about two-thirds of the total force engaged in the aircraft industry. The average monthly increase—about 2,000 since the beginning of the industry's expansion in 1950—is still continuing.

They Saved 29 Pilots

SOMETHING of an epic of its kind was the story, fully told last week, of how three Scottish villagers of Skipness, Argyleshire, saved 29 U.S.A.F. Sabre pilots. On November 29th last year, when the Sabres took off from Keflavik for Prestwick, 80 m.p.h. head-winds stretched the usual 90-min flight to over 2 hr. At Skipness was a radio beacon which had to be switched on manually. A Mr. MacGougan had the key and had volunteered to operate the beacon when needed. A telephone call from Prestwick was answered by a Miss Mary Cook, who cycled through a gale to Mr. MacGougan's house. She found that he was away, but had left the key with his wife. Together Miss Cook and Mrs. MacGougan faced the gale, opened up the beacon and switched it on. Thanks to their action, the Sabres landed safely, though with barely ten minutes' fuel. The beacon has since been replaced by Redifon continuously operating equipment.

FOURTH PROTOTYPE of the Gloster Javelin FAW. 1 (two Armstrong Siddeley Sapphires). Points to note are the revised wing plan-form, with "kinked" leading edge, and the slots (or, more explicitly, gaps) in the leading edges of the flaps. These can be seen immediately behind the serial numbers. Javelins are expected off the production lines later this year, ahead of schedule.

Knot Likely—Now Certain

THE Civil Aeronautics Board has ordered all American airline operators to adopt the use of knots and nautical miles by October 1st this year.

Opening in Technical Journalism

OUR sister journal *Aircraft Production* has a vacancy for a young editorial assistant. First-hand knowledge of modern engineering production processes is necessary and aircraft works experience (engine or airframe) is desirable, though not essential. Applicants should write, stating age and giving particulars of qualifications, to W. E. Goff, Editor, *Aircraft Production*, Dorset House, Stamford Street, S.E.1.

Service and Commercial Fuels

THOUGH it is widely known that wide-cut gasoline (AvTAG) is accepted as the standard R.A.F. turbine fuel, some misapprehension has evidently arisen as the result of a transcription error in our report of Sir Miles Thomas's recent Brancker Memorial Lecture; an unwanted "not" crept into the quotation of his remarks on the subject of fuels for commercial use. The relevant sentence should have read: "Although the R.A.F. had now decided to use a wide-cut gasoline instead of kerosine, the arguments for making this change did not attract the airline operator to the same extent, if at all."

Dectra and Delrac

TWO new long-range radio air-navigation systems, both originated by the Decca Navigator Co., and known by the above names, have been officially submitted to the fifth session of the Communications Division of I.C.A.O. at Montreal for consideration. Details will appear in a forthcoming issue.

F.R. in France

FOR the first time, Flight Refuelling, Ltd., have granted manufacturing rights for their products outside the United Kingdom and U.S.A.; it was announced last week-end that an agreement has been entered into with Société Carburator Zenith for the manufacture of all F.R. products other than those concerned with flight refuelling. The components will be manufactured at the Zenith factories in Lyons and will be marketed under the name Zenith-F.R. We hope to give further details next week.

H. V. ("Bob") Wright

MENTIONED last week in a note about appointments made by the Bristol Aeroplane Co. of Canada, Ltd., was H. V. ("Bob") Wright. We are now sorry to hear of his death, which occurred shortly after the news-item was sent from Montreal. He joined the parent company as an engine fitter soon after World War I, visited Canada to help with a Bristol engine installation, and later returned there, joining the Canadian Wright company. He rose to be its president; and when, after World War II, the company passed into other hands and was eventually acquired by Canadian Bristol, he found himself associated with his original employers. He was the Canadian company's managing director at the time of his death.

H.R.H. THE DUKE OF EDINBURGH inspects a smartly finished Pika target aircraft (Armstrong Siddeley Viper) during his Woomera visit. The ground control panel can be seen in this view.

CIVIL AVIATION

INDEPENDENTS' PROGRESS

ON March 30th the 52 member companies of the British Independent Air Transport Association held an informal gathering at which guests included the Minister of Transport and Civil Aviation, Mr. A. T. Lennox-Boyd, and his Parliamentary Secretary, Mr. J. Profumo. No speeches were made but the Association issued a written report describing the development of British independent air traffic since July 1952. In that month, it will be remembered, the Government introduced its present civil aviation policy, offering better security of operation to independent airlines: to date, this has encouraged the independent operators to apply to run services on 71 internal and 169 international routes. So far 37 internal and 69 international services have been approved by the Minister, and (with the exception of the all-freight routes, for which suitable aircraft are not yet available) most of these new-found rights are being put to good use.

In 1953, for the first time, the number of passengers carried on the independents' scheduled services was greater than the number carried on charter and trooping flights. The figures quoted below show that although the Corporations still carry the bulk of scheduled traffic the independents' efforts in this field have been greatly stepped up. The "Independent" totals, incidentally, refer to all British private airlines operating scheduled services and not solely to B.I.A.T.A. members.

	1952	1953	Per cent increase
B.E.A.	1,337,941	1,636,000	22
B.O.A.C.	272,972	287,100	5
Independents (scheduled services)...	121,938	238,673	95.7

However, these statistics tell only a part of the story, since they do not take distance into account. Passenger-miles flown on the independents' scheduled services totalled 52m in 1953, which compares with about 460m passenger-miles by B.E.A. And although independent scheduled services carried nearly as many passengers as B.O.A.C., the Corporation flew 136.5m ton-miles during that period compared with 7.1m ton-miles by the independents.

Taking into account distance as well as passenger totals, trooping and charter contracts remain responsible for the bulk of independent traffic. Aircraft operated by B.I.A.T.A. members on non-scheduled services last year carried 193,431 passengers (66.3 per cent more than in 1952), of whom nearly 120,000 were troops, and flew 46m ton-miles and 278m passenger-miles. These figures indicate clearly that most of the independents' revenue is still derived from non-scheduled services and contain no evidence that there has been any significant diversion of traffic from the Airways Corporations.

On December 31st last year B.I.A.T.A. members were operating a total fleet strength of 168 aircraft (14 more than at December 31st, 1952), of which all but 23 were multi-engined.

PROFIT—

SPEAKING in London on March 31st, Sir Miles Thomas, chairman of B.O.A.C., said: "Without letting go any secrets . . . I can say that this financial year we are just concluding at midnight tonight will show a very substantial profit." No further details were given, but it is reported that Sir Miles was referring to the "operating profit," from which interest on capital must be deducted. The sum is believed to be large enough to cover the interest and leave a surplus.

B.O.A.C.'s first profit was made in 1951-52, when £274,999 remained after payment of interest. In the financial year 1952-53 the Corporation's "operating profit" of £103,875 was turned into a deficit on payment of £942,539 interest; taking into account certain capital profits and other surpluses the net result for 1952-53 was an accumulated deficiency of £292,718.

Last November, in a message to the staff of B.O.A.C., the chairman said that operations during the first six months of the 1953-54 financial year had resulted in a net profit (interest paid) of £123,000. He added: "Provided we run into no unforeseen expenditure, and if we all pull together . . . I believe it is now within our power to earn sufficient profit this year to cover interest on capital in full—in other words to pay our way as a Corporation."

The news that B.O.A.C. have achieved this commendable objective casts doubt on earlier reports that the 10-week suspension of Comet services cost the Corporation about £500,000. At no time were aircraft chartered from other airlines, and comparatively few services were cancelled. By increasing the frequency of their Argonaut services, B.O.A.C. made up for the temporary loss of Comet capacity in the most efficient and economic way possible. So far as the Corporation's overall 1953-54 accounts are concerned, it seems probable that the effects of grounding the Comets have been exaggerated.

—AND LOSS

IT was announced on April 1st by Lord Douglas, chairman of B.E.A., that the Corporation's deficit for 1953-54 would show a slight increase on last year's loss of £1,459,131. This news was not unexpected; in fact, the Corporation's report for the financial year ended March 31st, 1953, stressed that over the following 12 months, "with heavy increased costs to shoulder, a decrease in deficit cannot be forecast."

Lord Douglas said that it was hoped to reduce the new deficit by 32 per cent in the year ahead. Both the chairman and chief executive have made it clear, however, that with its present commitments the Corporation cannot operate profitably. Apart from such factors as petrol tax (which will absorb £500,000 during 1954-55), low mail-pay and the cost of developing new aircraft such as the Viscount, the major problem remains the basic difficulty of operating short stages at a profit.

Broadly speaking, every B.E.A. route over 300 miles shows a profit and every one under 300 miles a loss. The average B.E.A. fare is £6 18s single compared with £80 for B.O.A.C., but there is a much closer relationship between operating costs: booking fees, take-off and landing charges, etc., must be met whether the stage flown is 100 miles or 2,000 miles.

B.I.A.T.A. PARTY: Some of the personalities present at the informal gathering, reported above, of the British Independent Air Transport Association: Top, left: Mr. Gerard d'Erlanger, Air Transport Advisory Council, with Mr. A. T. Lennox-Boyd, Minister of Transport and Civil Aviation. Top, centre: two former chief test pilots—Mr. Harvey Heyworth, Rolls-Royce, and Mr. David Bay, Percival Aircraft. Top, right: Mr. J. J. Fargher, Morton Air Services, and Mr. M. L. Thomas of Jersey Airlines. Below, left: The "B", "K" and "G" of B.K.S. Air Transport—Messrs. J. W. Barnby, T. D. Keegan and C. J. Stevens—with Mr. R. Lambert of Lep Air Services, Ltd. Below, centre: Three members of a famous family—Mr. L. C. Hunting, Mr. C. P. M. Hunting and Mr. P. U. Hunting. Below, right: W/C L. B. Elwin of Cambrian Air Services and Mr. S. A. Barnes, Silver City Airways.

"Flight" photographs

SERVICE AVIATION

Royal Air Force and Fleet Air Arm News

LITTLE GREY HOME IN THE WEST: Orbiting its base—Royal Naval Air Station Eglinton, Londonderry, Northern Ireland—is a production Fairey Gannet A.S.1 (Armstrong Siddeley Double Mamba turboprop). Gannets are now leaving Fairey's production line at a heartening rate, and the first squadron is forming at Royal Naval Air Station Ford

Two Flag Promotions

THE Admiralty has announced the promotion of Vice-Admiral Sir Charles E. Lambe, K.C.B., C.V.O., to the rank of Admiral and of Rear-Admiral Caspar John, C.B. to Vice-Admiral.

Both these officers have wide air experience. Ten years ago Sir Charles was in command of H.M.S. *Illustrious*, then serving in the Eastern Fleet, and his appointments since then include: Assistant Chief of Naval Staff (Air) at the Admiralty; Flag Officer Flying Training; Flag Officer Commanding the 3rd Aircraft Carrier Squadron, Home Fleet, in H.M.S. *Vengeance* and Flag Officer (Air) Home. As long ago as 1929 he qualified for his pilot's civil "A" licence and for a long period flew his own aircraft.

Vice-Admiral John is a son of the famous artist, Augustus John, and by many he will be remembered as a pilot in pre-war air races. Between the two wars he served in a number of carriers and in 1941 became the Director-General and later Chief Naval Representative for Naval Aircraft Development and Production at the Ministry of Aircraft Production. In 1943 he became Head of the British Naval Air Service Representation at Washington. Later in the war he had command of the carriers *Pretoria Castle* and *Ocean*. After the war ended he continued his association with Naval aviation and in 1948 he was appointed to command R.N. Air Station Lossiemouth, Scotland, before serving in the Admiralty as Deputy Chief of Naval Air Equipment and later as Director of Air Organization and Training.

R.A.A.F. Avon-Sabres

IN anticipation of delivery of Avon-Sabres to R.A.A.F. fighter units, a number of technicians have gone to the Commonwealth Aircraft Corporation factory at Fishermens Bend, near Melbourne, for a course in the handling and maintenance of the new aircraft.

The Rolls-Royce-engined Sabre is being produced in Australia only, by the Commonwealth Aircraft Corporation. The prototype first flew last summer.

Reserve Flights

LAST week, at a conference held at the Air Ministry, Mr. George Ward, Under-Secretary of State for Air, amplified the statement he made earlier in the House of Commons concerning the reserve flight scheme.

The background of the scheme is the need for very speedy mobilization of the R.A.F. on the outbreak of war. Air defences must be in full operation and fully manned immediately; and these defences, as Mr. Ward pointed out, consist not only of Fighter Command with its radar system of early warning and fighter control, but of Bomber Command also, which must be ready to strike at once.

If this urgency is to be achieved, it is obvious that the reservists bringing the R.A.F. up to war strength must be able to carry out their work without further training and without loss of time by being called to personnel transit centres and redirected from there. Under the new arrangement reservists will be allotted in peacetime to specific R.A.F. stations at home and these, in general, will be their wartime stations.

It is hoped, too, that the scheme will help to keep up the interest of the reservists in their work and to encourage them to take part in the social and sporting activities of the station to which they are posted. It is realized that these aims will be more easily achieved at stations lying close to the more densely populated areas and that a weak spot in the scheme is the finding of the personnel to man a reserve flight at an isolated station.

Reserve flights will consist of officers and airmen and members of the W.R.A.F. from all classes of the Reserve, whether they are liable to do peacetime training or not. Only those with a peacetime liability will be called up for training, but volunteers from groups having no peacetime liability would be particularly welcome. A special appeal is made to these people, such as Class G men and former members of the W.R.A.F., to train voluntarily with reserve flights. They would be asked to transfer from their present reserve class to the R.A.F.V.R. All members of the reserve flights will be paid at the new R.A.F. rates for the training they do and will receive bounties and travelling allowances.

The scheme is being introduced in two phases. The first started last week-end and covered the Control and Reporting Units of the Fighter Command Radar Organization and some other signal units of No. 90 Group. The second phase is due to start on July 1st and will cover the remainder of Fighter Command and be extended to Bomber Command and some Coastal Command stations.

The first instructions which reservists will receive will include mobilization instructions, a railway warrant, a draft value 10s and particulars of the flight to which the reservist has been posted. These are for use only on mobilization. Shortly afterwards the reservist will receive a letter from the commanding officer of his flight, who will deal with all problems arising.

In the coming year it is expected that these instructions will be sent to some 25,000 reservists—16,000 of whom will be called up. Of this 16,000 approximately 13,000 will be National Service Reserve.

The scheme does not extend to aircrew; a special arrangement for these is to be announced later. The remainder of the reserve, that is to say those not organized into reserve flights, will continue to be administered by Home Command.

Kemsley Trust Trophy

THE first winners of the Kemsley Trust Flying Trophy are No. 1831 Squadron, R.N.V.R. (Lt-Cdr. W. A. Storey, R.N.V.R.), based at Stretton, (near Warrington, Lancashire. The Trophy was presented last December by Viscount Kemsley and the trustee of the Kemsley Flying Trust, and is awarded to the R.N.V.R. air squadron winning an annual competition based on operational flying training.

Lord Kemsley will hand the trophy to Vice-Admiral A. K. Scott-Moncrieff, Admiral Commanding Reserves, at a ceremony held on board H.M.S. *President*, at the Victoria Embankment, London, at 5.30 p.m. on April 8th. Vice-Admiral Scott-Moncrieff will then present the trophy to Cdr. R. I. Gilchrist, M.B.E., R.N.V.R., who commands the Northern Air Division, of which No. 1831 forms part, and who led the winning squadron team.

Air Power at Sea

H.M.S. THESEUS

In the records of the names of British warships H.M.S. *Theseus* appears three times: first as a third-rate commissioned in 1786, most recently as the light fleet carrier *Theseus* of 13,350 tons launched in 1944. Commissioned in peace, this ship yet has a history of action as one of Britain's principal naval units engaged in the Korean war. In the support of ground formations her aircraft, including squadrons of Fairey Fireflies, flew 3,446 operational sorties and made 4,594 deck landings, maintaining a standard of efficiency in carrier operation seldom equalled. Her reconnaissance aircraft (mainly Fairey Fireflies) covered 23,492,730 square miles.

H.M.S. *Theseus* represents a class of carrier which will, in the near future, operate Gannets, the Royal Navy's latest and most powerful anti-submarine aircraft designed and built by Fairey.

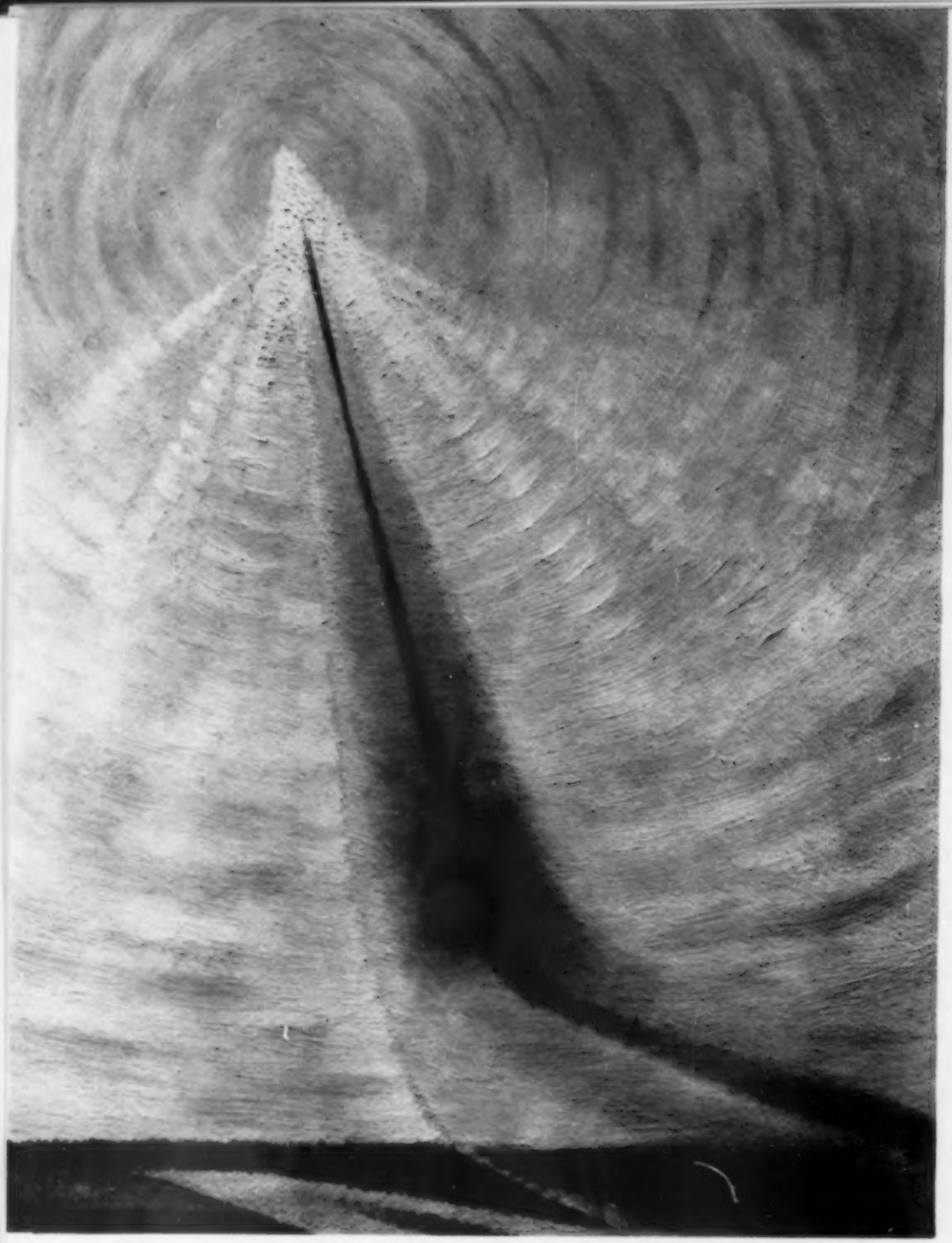
Crown copyright of the badge of H.M.S. Theseus is reserved and reproduction is made by permission of the Admiralty and H.M. Stationery Office.

FAIREY

Powered by an Armstrong Siddeley "Double Mamba"

GANNET

THE FAIREY AVIATION COMPANY LIMITED · HAYES · MIDDLESEX



This painting by Roy Nockolds, the first of a series of abstract designs specially commissioned by Armstrong Siddeley, gives something of the feeling of the immense thrust developed by the Sapphire turbojet propelling a fighting aircraft to its operational height in a matter of minutes . . . an essential requirement for the modern military aeroplane.

SAPPHIRE
has been chosen for

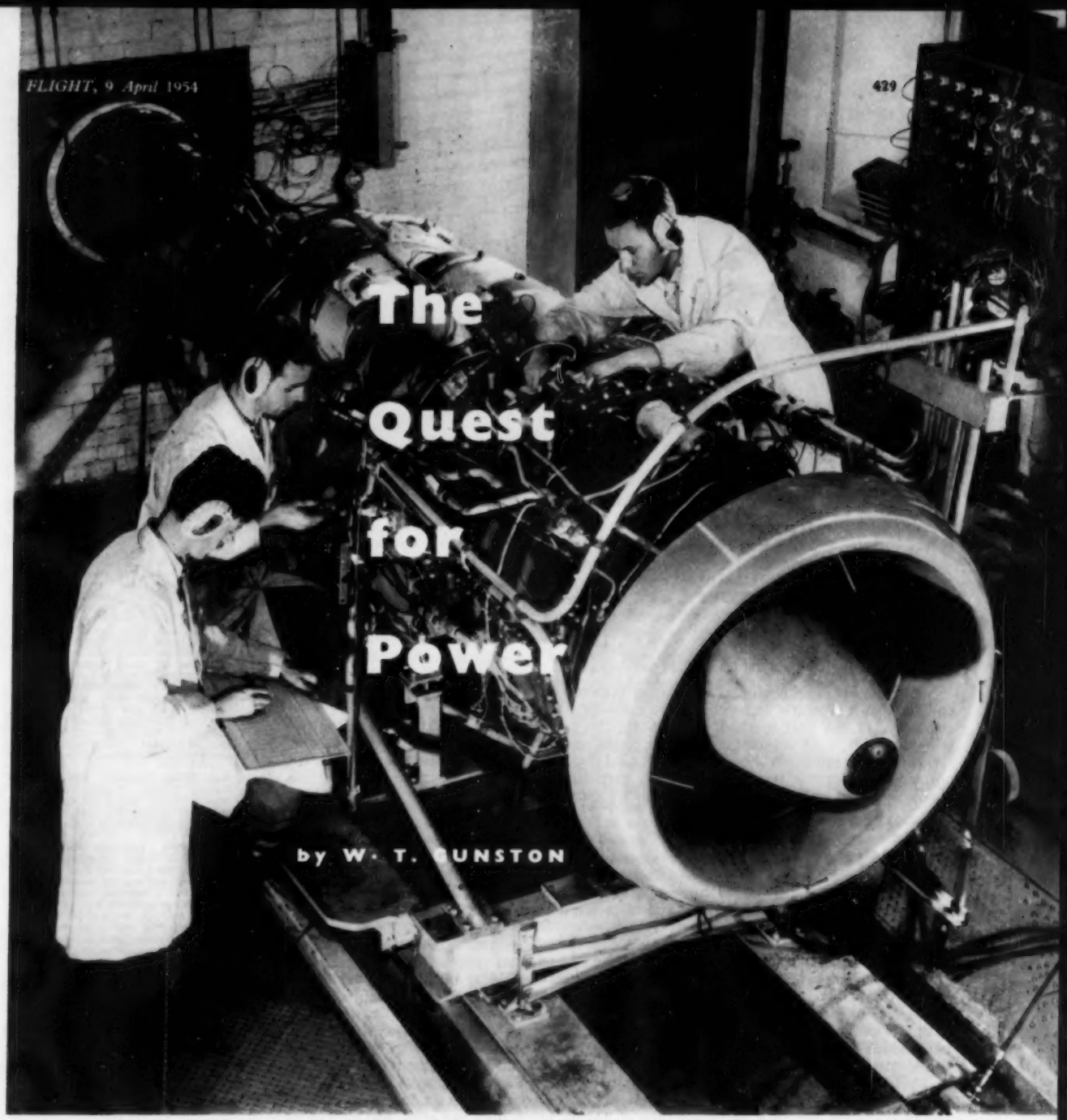
★ The Sapphire is manufactured under licence by the Wright Aeronautical Division of the Curtiss-Wright Corporation in the U.S.A., where it is known as the Wright J.65.

The vital strategic importance of the Sapphire is emphasized by the fact that it is chosen to power the following aircraft, for the air forces of the N.A.T.O. powers . . .

THE HAWKER HUNTER F.2 *fighter*
THE GLOSTER JAVELIN *all-weather fighter*
★ **THE REPUBLIC F.84F** (*Thunderstreak*) *fighter*
THE HANDLEY PAGE VICTOR *crescent-wing bomber*
★ **THE MARTIN B57** (*Canberra*) *bomber*

ARMSTRONG SIDDELEY

ARMSTRONG SIDDELEY MOTORS LIMITED · COVENTRY
Members of the Hawker Siddeley Group



The Quest for Power

1

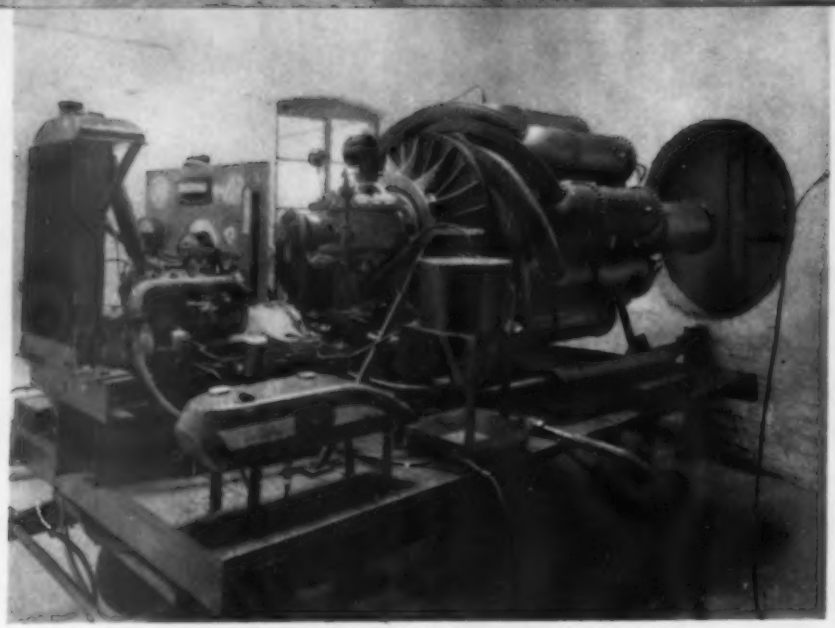
by W. T. GUNSTON

Avro Canada Orenda in test cell.

THIS is the first occasion on which *Flight*—or to the best of our knowledge, any other aeronautical journal—has produced a special issue reviewing the work of the world's aero-engine manufacturers. The appearance of this issue has not been timed to coincide with any particular development in the field of aircraft propulsion: indeed, to do so would not be easy, for each day marks a further advance in man's inexorable quest for power.

Many companies throughout the world are each making a special contribution to this quest and, so that they may have a place in this issue, some of the work of each company in relation to engine manufacture is briefly noted in a special column on each of the following 15 pages. This condensed review of the contributions of the more important ancillary firms is a particularly potent indication of the enormous scale of aero-engine development today.

The main story which follows is intended to satisfy a wide field of interests. It is an outline of the broad principles along which modern aero engines are developed. Great Britain is proving herself particularly capable in this highest of all branches of engineering, which calls for the utmost skill and experience in many scientific fields. That we have many engineers with such skill and experience is not only a cause for satisfaction, but also, if this narrative is to have



The beginning of it all: the twice-rebuilt Whittle WU on its ingenious, if primitive, test-bed. This engine ran in October, 1938, and was the only British turbojet until late 1940.

The Quest for Power . . .

a message, a matter of consequence to us all. If we are to retain our present satisfactory position, many of our younger readers must do some aero-engine development of their own in the years to come.

There are such profound differences between the various families of modern aero engines that it is clearly impracticable to consider all the various types at once. We have decided that the best method of attacking the subject is to consider turbojets first, following this with comments on turboprops, piston engines, pulsejets, ramjets and rockets, in that order. It should be understood that the techniques described hereafter do not, unless otherwise stated, refer to any particular company. As far as possible, the problems posed and the methods of attack are common to all.

TURBOJETS It is now about ten years since the first military jet aircraft became operational, and two years since the Comet became the first turbojet airliner to enter commercial service. In most countries, more effort is being accorded gas turbine development than any other single type of prime mover, although this may not be the case in another ten years.

A new engine may be built to meet definite requirements, or it may be a complete private venture undertaken by a company in the hope that an application will materialize. In Great Britain, some of our most important engines—including the Conway and Gyron—were originally conceived in the "back rooms" of private companies in an effort to take a huge leap ahead of current thought, and so spur airframe manufacturers to make similar advances in the knowledge that a suitable engine would be there when needed. But most new British engines begin in a large building not far from London's Oxford Street, where the Ministry of Supply's Directorate of Engine Research and Development has its offices.

This immensely valuable Government department is continuously sifting engine requirements for as far ahead as can reasonably be foreseen. When a number of requirements appear to call for a particular type of engine which does not exist, and cannot be produced by the modification of one already built, all the relevant factors are, figuratively speaking, cast into the melting pot and shaken up to emerge as a precisely-worded M.o.S. specification—let us say, for a large turbojet.

This specification is studied by the engine manufacturers and, if the company decides to "have a go," a high proportion of the engineering staff will be committed to about six months' of solid paper work, beginning with an appraisal of the Ministry's own calculations, and going on with detail design of the complete engine. Some of the work is of an extremely complex nature, which can only be eased by the purchase of large electronic or electric calculating machinery. All the basic research departments will be involved, together with the performance section, stress office and one or more drawing offices. The results of this labour are condensed into a massive brochure, which is then submitted to the M.o.S. for consideration.

If the company's tender were to be rejected, the work so far done would be almost completely wasted. But in Britain few firms are active in each field and, in any case, it has been Government policy to sponsor development of more than one engine in each class, largely as an insurance against either engine not developing as rapidly or as well as it should. On the other hand, it is probable that, with the increasing cost and complexity of modern power units, such duplication of effort is no longer possible.

After numerous meetings at all levels, the Ministry may accept the tender and tell the company to go ahead. If this is the case, a development contract is worked out,

MANUFACTURERS AND PRODUCTS

Accles and Pollock, Ltd., Oldbury, Birmingham, have for many months been drawing tubes in Fortiweld and Titanium, as well as being in volume production with difficult jobs in easier materials.

Aerotec Corporation, Greenwich, Connecticut, have a new series of M800 switches and valves which can be used with concentrated nitric acid, liquid oxygen, water/alcohol, petrol or hydraulic fluids. On the B-47, for example, the M818 resists vibration of 10 g acceleration up to a frequency of 500 c.p.s., and can withstand surge pressures of 120 lb/sq in without changing its setting.

Aircraft Steel Structures, Ltd., Anadell Street, London, W.6, manufacture a variety of precision castings which include the complete range of metallic parts for Dowty fuel pumps and spill burners. They supply these in a completely finished state.

AiResearch Division of the Garrett Corporation, Los Angeles 45, California, are leading manufacturers of air-turbine refrigeration equipment, heat-transfer equipment, gas turbine/compressor or shaft-drive sets, pneumatic motors, electronic controls, turbojet, turboprop, ramjet, rocket and piston engine components, and other equipment. One of their more recent developments is an enormous saving obtained by hot extrusion of small turbine wheels and compressors (one-piece units, with blades). With diameters between 2in and 4½in, and weights between 2 oz and 1½ lb, about 100 per hour are being turned out from each 1,100-ton press, with a tolerance of 0.001in. Aluminium alloy is used, and the grainflow is very good.

Auto-Klean Strainers, Ltd., Lascar House, Staines Road, Hounslow, Middx, make filters for many piston and gas-turbine aero engines, including the fuel filter of the Goblin.

Automotive Products Co., Ltd., Tachbrook Road, Leamington Spa, manufacture Lockheed-Avery flexible pipes and self-sealing couplings, and Purolator filters—in addition to much other airborne and automotive equipment. Up to 4,050 lb/sq in can be accepted by the flexible hose, and the quick-release couplings include a range for pressure-fuelling. Purolator filters employ either a coil of special wire (on the edge-filtration principle) or a "Micronic" element.

Avery-Hardoll, Ltd., Oakcroft Road, Tolworth, Surrey, manufacture aircraft fuelling equipment of all types, and they are also principal suppliers of fuel meters used in gas-turbine rig and bench testing.

Avica Equipment, Ltd., 1, Adams Place, Holloway Road, London, N.7 (also at Portsmouth, R.I., U.S.A.), specialize in stainless-steel flexible hose assemblies. In America, Avica piping is widely used around turbojets as a carrier of air at over 700 deg F, and for other purposes; in England, Avica flexible piping is working with all kinds of liquids (including liquid oxygen and other gases under pressure at below −100 deg C. Corrosive gases are also catered for, at 350 deg C if necessary).

Bendix International, 72 Fifth Avenue, New York 11, market the products of the many divisions of the Bendix Aviation Corporation. These include every conceivable form of fuel-system accessory, ignition and starting equipment, and most other engine ancillary devices. Typical examples of fuel-system equipment are the TA-A1 afterburner fuel pump for the J33, the TP-A6 hydraulic fuel metering control for the T40 double turboprop, and a variety of electronic amplifiers for complete co-ordinated fuel systems. In the realm of starting equipment, Bendix prepared to make the Rotax monofuel starter, but

found that availability of iso-propyl nitrate was poor; accordingly they redesigned the starter to burn a stoichiometric fuel/air mixture, and the resulting starter is now made not only by Bendix but also by the original company, Rotax!

Birmingham Aluminium Casting (1903), Ltd., Birmid Works, Smethwick, Birmingham, produce aluminium, magnesium and zinc-base castings by a variety of processes. Typical engine parts include the compressor casings for the Olympus and for many Avons. The Olympus component is in four parts, the low-pressure halves being in ZRB-1 magnesium-zirconium alloy and the high-pressure pieces being steel. Birmal sand-cast the ZRB-1 part, with a half-weight of 114 lb. A half-casing for an Avon compressor is a particularly fine piece of work, weighing 149 lb as-cast with stator blade grooves. Even in the latest Avons, this is entirely in light alloy, although how it is kept cool cannot yet be revealed.

B.M.B. (Sales), Ltd., 2 Balfour Place, Mount Street, London, W.1, market British Manufactured Bearings, which are available in such tiny sizes as 1mm or 0.040in bore and 4mm or $\frac{1}{4}$in O.D. Miniature balls are made in various tolerances down to one-millionth of an inch, and a range of balls and bearings is available in more normal sizes.

Thomas Bolton and Sons, Ltd., Widnes, Lancs, make copper and copper-base alloys which are standard supplies to British engine manufacturers, either in the form of finished or semi-finished machined components.

Bowden (Engineers), Ltd., Flexible Pipe Division, Willesden Junction, London, N.W.10, have developed a flexible hose with swivel-type end-fittings, tested and approved for use at 5,000 lb/sq in and cleared for high-temperature applications. The reinforcing wires are interlocked with the end fittings; a single or double braid can be employed, the outer cover being a flame-resisting neoprene sheath and the inner lining a smooth layer of polyester plastic, fitting the hose for liquid or gas service. This piping is becoming accepted in a number of arduous turbojet applications.

British Insulated Callender's Cables, Ltd., 21 Bloomsbury Street, London, W.C.1, provide every type of aircraft cable, including "Pren" (−30 to 90 deg C), "Glasil" (−75 to 150 deg C) and "Glasef" (−75 to 250 deg C). The latter, with p.t.f.e. insulation, has heat and chemical stability sufficient for its wide adoption as the cable for turbojet high-energy igniter leads.

British Thomson-Houston Co., Ltd., Coventry, produce Maxwell speed indicators with which engine r.p.m. can be measured to an accuracy of 0.1 per cent. Twelve speed ranges are provided for, the widest being up to 48,000 r.p.m. The device is essentially a Wheatstone-bridge circuit, one arm of which is an accurately calibrated capacitor which is charged and discharged at a rate proportional to the frequency of a signal emitted by a generator coupled to the engine. B.T.H. airborne equipment includes, in addition to complete electric systems, electric and cartridge starters. The single-breech cartridge starter fitted to early Canberras is well known, and the company have followed this up with TBS 720 triple-shot starters which lie under the extended nose spinner of several types of Avon. The TBS 720 is in production at the new West Chirton factory for Swifts and Hunters.

British Timken, Ltd., Duston, Northants, and their subsidiary company Fischer Bearings Co., are major manufacturers of roller, ball and other types of bearings for all forms of aero engine, and for helicopter drives.

Brown Bayley Steels, Ltd., Leeds Road, Sheffield 9, have, as examples of their work, the casing around the Ghost combustion chamber rear portion (D.T.D.493) and the turbine/

possibly calling for the supply of about six complete prototype engines, and six additional complete sets of rough, unmachined parts. This, of course, is a compromise; if all were to go well, the second six engines could be rapidly constructed while if, as usually happens, the design of the engine were to be changed during development, the rough parts could be scrapped without too much work having been wasted on them.

With the contract signed, the brochure is returned to the company and, so detailed is this document, very little further work is necessary before drawings can be released for the manufacture of parts for the first set of prototype engines. Actually, a great deal of experimental work will already be under way, particularly on those parts of the engine which are expected to offer thorny problems.

In the early days of gas turbines, this was rarely possible, for the whole engine was then expected to cause trouble. Today, far more is known about all kinds of gas turbines, and development can proceed immeasurably more rapidly. But it would paint a most inaccurate picture if it were not said that the demands upon the engine designer have increased in even greater proportion, so that his task is by no means easier than it was ten years ago. This raises numerous points which, though they tend to sidetrack discussion, are nevertheless worthy of attention.

Every year, the pressures and temperatures inside gas turbines are made progressively higher as the designer seeks more power and efficiency from an engine of ever smaller compass. The same effect is, of course, felt in almost every other kind of power unit, but the pace of development is so much more rapid with the gas turbine that one might almost wonder where it is all going to end. Every material has its limits—sometimes lower than laboratory testing may lead one to believe—and it appears that there must be some quite definite limits to both pressure and temperature in practical aircraft gas turbines with present nickel-chrome alloys. An obvious rejoinder is the suggestion that better materials should be sought; but, in spite of the superb past performance by metallurgists, it is clear that there are optimum alloys which must sooner or later be reached. What happens then is anybody's guess. Stagnation is unthinkable; perhaps some hopes may be pinned on non-metallic materials.

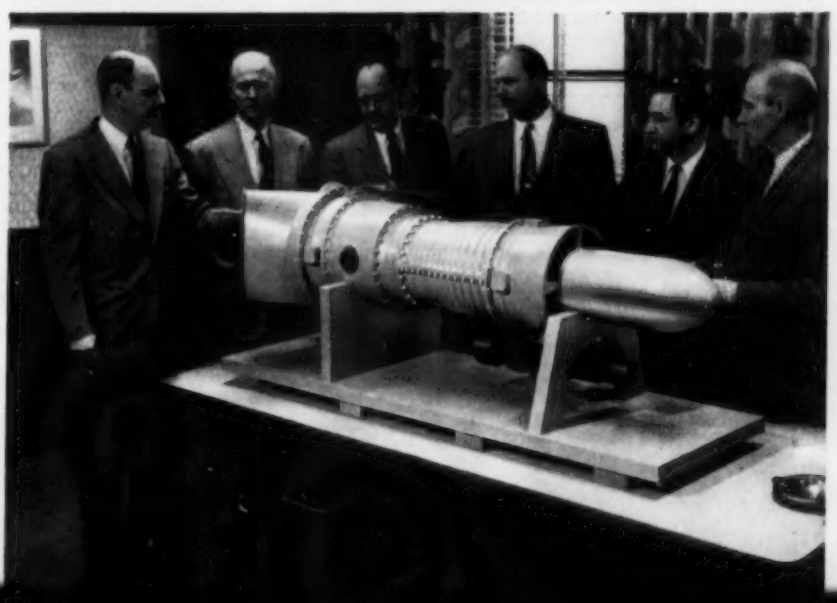
Blade cooling is generally agreed to be an essential stepping-stone to future development, possibly combined with inter-cooling, as has been found necessary on piston engines. Ceramic/metal blades are another possibility, which have yet to fulfil their promise. Designers (as distinct from basic-research workers) are also devoting time to supersonic compressors. It may be possible to increase the output of some present engines by attaching one or more transonic stages to the front of the existing axial compressor. Coupled with such advances may be the provision of variable-pitch inter-stage blading throughout the compressor and variable intakes, and convergent/divergent propulsive nozzles, all controlled by an electronic (or, more likely, magnetic amplifier) "black box" sensitive to throttle position.

A common error in the past was to design a turbojet to give its maximum thrust at the operating point of maximum permissible gas temperature. A weakness of this policy was that it allowed little room for "stretch" so as to release the full development potential of the engine. Today, it is more usual to design the engine to give full power with the maximum temperature a little below the limit, thus permitting the temperature to be raised as development progresses. The total engine running time may, in fact, be related to temperature, starting off gently to absorb plenty of data, and then working on up to the limits.

But in spite of these high-temperature problems, the position today is fairly happy, and development of the hypothetical turbojet can proceed with available materials, although these materials will undoubtedly be pushed to the limit of their capabilities. It is largely this characteristic of working to the limit which prevents gas turbine development from getting progressively easier and quicker.

In the event, there will probably be about one year between the start of design and the first cutting of metal. But before actual pieces of engine begin to appear, rig testing of different parts should have been in progress for a considerable time. If, for

The beginning of a new engine: the General Electric XT58 turboprop being examined in full-size mock-up form earlier this year.



The Quest for Power . . .

example, the designer is aiming at a low specific fuel consumption, obtained by employing an exceptionally high compression ratio, then individual compressor blades and cascades will be examined more extensively than usual, followed by tests on two or more complete stages, culminating in rig tests of a complete compressor.

The function of the compressor is, as its name implies, compression of the intake air to the highest possible pressure preparatory to combustion. All that is needed to test the compressor is, therefore, an adequate supply of shaft power, together with a means for admitting and exhaling the pumped airflow. This may not appear difficult to provide, but if the new compressor is very big—suppose it is for a 30,000 lb thrust turbojet—there may not be any rig in the country capable of running it in anything like its design conditions.

Accordingly, a new test-house has to be built at a cost of between £500,000 and £1,000,000, with plant capable of providing sufficient power. Various types of equipment have been tried, some decidedly better than others. Space and weight are not primary problems, so marine machinery can sometimes afford an economical solution. Armstrong Siddeleys at Anstey, for example, employ high-pressure steam boilers and turbines from a former Royal Navy destroyer. Bristols have chosen batteries of electric motors, while Allison, in America, have produced a novel layout, obtaining power from batteries of turbojets and turboprops. Although not particularly attractive from the viewpoints of simplicity, flexibility and running cost, this last-named installation provides 40,000 h.p. and uses components of proven aero engines. Incidentally, the set-up is an excellent example of the manner in which components of a gas turbine can be run by themselves, provided that their designed operating limits are respected. Not counting the test compressor, the Allison installation employs parts of 26 separate engines of four types.

While the big test station is being built, work can proceed on dimensionally similar models of the new compressor. It is also possible to make a full-size compressor and test it in an airflow at reduced pressure, so economizing in power requirements. This can provide a very great deal of information on how near the compressor performance is to the design requirements. These test models can be made rapidly and cheaply by employing inferior materials, such as straightforward aluminium or any available plastic.

Although the primary aim of the rig testing is the development of the compressor to give optimum performance, it is also essential that mechanical strength and vibration and resonance characteristics should be thoroughly worked out before the first engine is built. Straightforward mechanical testing, which embraces the entire structure of the engine, is similar in some respects to structural testing of airframes. Photo-elastic stress analysis is now an accepted method in this work. One aspect not found in aircraft construction is whirl testing of the rotating parts of the engine in a sunken test pit below ground level. Here, the whole assembly is run far beyond designed speed—possibly until destruction occurs from centrifugal loading. After a destruction test, nothing is left but a heap of splinters; but from these the trained eye can learn a great deal, particularly if strain-gauging and a high-speed or stroboscopic film record has been undertaken. It is now becoming common practice to evacuate the test chamber of air in order to cut down the power required by such testing.

In the complete engine, the compressor is driven by one or more turbine stages, rotated by a flow of hot gas from the combustion chambers. To test a turbine fully, a flow of hot gas is therefore needed, although cold testing is adequate in the initial stages. In testing compressors, the power requirements can be cut down by examining one or two stages at a time. A turbine can be run only with the whole gas flow.

Turbine work starts with a large number of blade rigs and cascades with which general profile investigations are undertaken. Pressure measurements may be made from small orifices on the blade surfaces, while pitot measurements can be obtained through tiny probes with pressure heads equal in size to sections of hypodermic needle. The results of such tests keep the company's mathematicians busy for weeks unless an electronic calculator is employed.

For cold testing, it is possible to use a light-alloy turbine driven against a dynamometer brake by air delivered from huge compressor sets. At the same time, blades made of appropriate high-temperature alloys are tested for resonance and fatigue, either electromagnetically or by subjecting them to a hot-air blast applied down the blade from the tip. Vibration characteristics may also be studied by clamping the blade at the root, sprinkling it with a suitable powder and playing upon it with a violin bow.

The combustion chamber is probably no longer the most difficult part of the engine to get working really well. In this country, the design of burners and "cans" is largely the prerogative of one company, and frequently this company is supplied with all the relevant requirements by the engine manufacturer and left—with guidance—to get on with the job. Various sets of combustion systems are then set up in rigs and air from industrial compressors blown through them in the correct conditions. Something can also be learnt by testing the chamber with a flow of liquid: for instance, how the assembly will accept high pressures and large flows.

The most promising chamber will then be run hot with the specified fuel, and checks made to see that no hot spots exist. The delivery from the combustion chamber is then probed for uniformity across the section, both in velocity and temperature. The rig is run under all possible flight conditions, particularly those met at high altitude, where reduced air pressure affects flame stability adversely; the high altitude re-light case is probably the most difficult requirement of all. Tests of fuel and ignition systems proceed at the same time. It may be noted that, with the almost universal adoption of annular or cannular combustion chambers, it is still possible to rig-test a portion of such

compressor central hub shaft and extension shaft for the same engine (S.11 nickel-chrome steel). The company also make Proteus flame tubes, the material being B.A.C.E.183 heat-resistant stainless steel.

The David Brown Foundries Co., Penistone, near Sheffield, manufacture all sizes of aero-engine steel castings.

Bryans Aerequipment, Ltd., Willow Lane, Mitcham Junction, Surrey, ensure that engine-test equipment is itself accurate by providing such test and calibration gear as a portable testing unit for jet-pipe thermocouples, rear-bearing thermometers, voltage compensators and similar temperature-measuring systems.

Burnley Aircraft Products, Ltd., Fulledge Works, Burnley, Lancs, were recently the subject of an article in this journal, describing their big output of sheet-metal ware for the "hot-end" of most British engines. Their products include flame tubes, afterburners and insulating blankets.

The Carbon Dioxide Co., Ltd., Great Burgh, Epsom, Surrey, have, in association with the Distillers Co., Ltd., developed the "CeDeCut" technique of using CO_2 as a machine-tool coolant, which was demonstrated when the Rolls-Royce East Kilbride plant was opened. Most encouraging results have been obtained, particularly with the tougher gas-turbine alloys, including Nimonic and ni-cr-mo steels. CO_2 is also widely used in America on titanium alloys.

The Carborundum Co., Niagara Falls, New York, are the manufacturers of Fiberfrax, a synthetic heat-resisting fibre formed by the action of an air blast on a molten aluminium oxide/silica mix. It is widely employed as a basis for thermal insulation, and a particular application is its use in an afterburner flameholder as a cushion between the refractory segments and their metal retaining ring. Another of the company's refractories is Niafrax, which is extremely resistant to combined high-temperature corrosion and erosion. It is basically silicon carbide bonded with silicon nitride to give resistance to thermal shock far greater than has been possible with clay bonding. Niafrax is being used at temperatures up to 3,500 deg F, and is in pilot production for numerous guided-weapon rocket motors as a nozzle and combustion liner. In nozzle form it is available in throat diameters between ½in and about 10in.

Carron Parlanti, Ltd., Falkirk, Stirlingshire, Scotland, have patented an advanced moulding process in which the dies are made of anodized aluminium. With such dies, "Ni-forge" stress-free castings are produced in all standard alloys, these castings having unusually good properties more akin to those of a forging. A principal product by the Carron Parlanti process is compressor blading.

Cementation (Muffelite), Ltd., 39 Victoria Street, London, S.W.1, make silencing installations for all kinds of test-bed. At the Patchway facility of the Bristol Engine Division, for example, the twin Olympus test-houses have the following layout: a flow of entrained air, seven or eight times that passing through the engine, cools the flow so that it can be passed through a diffuser section. It then traverses a splitting section formed from acoustic panels and including four fairly sharp bends, and finally passes out vertically to atmosphere. Much of the structure is a concrete monolith, pin-jointed for expansion, and the inner surface temperature is kept below 75 deg C by a 4in mineral-wool lining covered by reflecting aluminium.

The Chemical and Insulating Co., Ltd., Darlington, hold the British Empire and European rights for "Refrasil," described under the H. I. Thompson company.

Consolidated Engineering Corporation, 300 North Sierra Madre Villa, Pasadena 8, California, have developed a vibration recorder for jet

ESCAPE

Ejections in level flight at 200 feet, at speeds of 600 m.p.h., have been made with the Martin-Baker Patent fully automatic ejection seat, the result of seven years intensive development; in the past two years we have developed the new Lightweight fully automatic Ejection Seat with an installed weight of only 50 lb.

Patented in the principal countries of the world and certain patents pending

MARTIN-BAKER

AIRCRAFT COMPANY LIMITED · HIGHER DENHAM · NEAR UXBRIDGE · MIDDLESEX

The flying-boat

FALLACIES AND FACTS

On the subject of water-based aircraft, expert and lay opinion is divided as upon few other aeronautical subjects. But the debate and discussion are not always reasoned and clear-cut. Too many arguments are complicated by false assumptions . . . by outdated data . . . by plain prejudice.

On this page we champion the flying-boat and challenge 'They'—all those who wittingly or unwittingly perpetuate flying-boat fallacies.

★ **THEY SAY** that the flying-boat has had its day, that it can no longer compete with the landplane.

THE TRUTH is that thanks to behind-the-scenes aerodynamic and hydrodynamic research the flying-boat has never been so well equipped to meet Britain's military and civil needs.

★ **THEY LEAVE OUT** of the question recent vital progress on the other side of the Atlantic.

THE FACTS are that in the United States, where the significance of water-based aircraft has been more fully appreciated, flying-boats are in active development and production.

★ **THEY QUOTE** facts and figures based on the performance of those grand old stagers the *Sunderland* and the *Empire Flying-boat*.

THEY FORGET that these designs are older than most National Servicemen — and as relevant to the flying-boat of to-day as the Hurricane to the Hunter.

★ **THEY ASK** why water-based aircraft, with all that is claimed for them, have been so neglected in this country.

THEY OVERLOOK the vast war-time expenditure on runway aerodromes, both here and throughout the world. It was this, short term view though it was, which kept the landplane up and the flying-boat down.

★ **THEY ARGUE** that it is now too late to revert to the flying-boat, for either military or commercial purposes.

THE RETORT is that the insistent demand for greater loads and longer ranges can only be met by bigger aircraft. While the prohibitive cost of artificial runways of sufficient length rules out larger landplanes, there is practically no limit to the size of future flying-boats. Their runways will remain as they are now — natural, free and bomb-proof.

★ **THEY THINK** only in terms of the present and the immediate future.

THEY NEGLECT the almost certain advent of atomic power for aircraft. The implications are highly important. First, only very large aircraft will be able to carry the heavy power plant and shielding. Secondly, since fuel consumption will be negligible, wing loading at landing will be high. Both these facts support the belief that atomic aircraft will have to be large flying-boats. At 140 tons, the *Princess* is their forerunner.

★ **THEY DECLARE** that flying-boats cannot operate in rough conditions and are always difficult to manœuvre and to moor.

THEY ARE IGNORANT of the vast progress made in hull design. The modern flying-boat is able to operate in almost any weather and can be virtually independent of surface craft.

★ **THEY COMPLAIN** that flying-boats are slower than landplanes.

THE FACT is that the latest water-based aircraft with jet and prop-jet engines are just as fast as comparable landplanes — and offer greater range.

★ **THEY TALK** about the necessity for costly artificial basins or lagoons.

THE REALITY is that modern flying-boats can operate from natural stretches of water such as the Solent. The cost of base facilities? A fraction of that of landplane airports.

Well, which do you favour — fallacies or *FACTS?*

AN ANNOUNCEMENT BY **SAUNDERS-ROE**

and rocket applications. The pick-up is a one-inch cube weighing 1.3 oz, and the system is that an electrical generator sends out a signal of a strength proportional to the acceleration of the object to which it is attached. Temperature limit is 300 deg F, or 500 deg for short periods.

Control Products, Inc., 306 Sussex Street, Harrison, New Jersey, have developed a range of thermal switches for rockets, afterburners, and similar applications where ambient temperature may rise to 1,500 deg. F.

Coopers Mechanical Joints, Ltd., 14 Liverpool Road, Slough, Bucks, are makers of most forms of jointing materials and gaskets to several D.T.D. specs., and also shims, washers and gauze strainers.

Cross Manufacturing Co. (1938), Ltd., Combe Down, Bath, Somerset, have a range of wire thread inserts, used in both new equipment and for salvage.

John Curran, Ltd., Curran Road, Cardiff, are major suppliers of aero-engine test equipment. By continuous development, Curran test benches and ancillary equipment are always available for each new type of piston, turbojet, and turboprop engine; for the last-named type of unit, a particularly noteworthy installation is the torque-measuring test bench developed last year for the Dart, upon which control connection and calibration can be performed at the same time as accurate measurement of power output.

Davis, Wyna and Andrews, Ltd., of Cheltenham, make research and development equipment for such purposes as the investigation of vibration, or the accurate measuring of speeds, stresses or temperatures.

Delaney Gallay, Ltd., Edgware Road, London, N.W.2, are specialists in the design and manufacture of heat-transfer equipment. A recent range of products, for various high-speed applications, are liquid/liquid heat exchangers, a typical example (6in diam and 21in overall) having synthetic turbine oil as the cooled flow, the heat being taken away by kerosine at 1,000 p.s.i. The unit is a U-tube formation working on the cross-counterflow principle. Gallay are also co-operating with the Johns-Manville company of New York (q.v.) in the supply of Thermoflex heat-insulating tailored blankets for turbojet tailpipes and afterburners.

Detuners, Ltd., Flowers Mews, London, N.19, a division of the acoustical-engineering firm of Horace W. Cullum and Co., specialize in the design and manufacture of silencers for gas-turbine test beds. A Detuner is a long cylinder, largely in mild steel, into which the engine under test exhausts. The flow velocity and temperature are reduced by an entrained airflow—without any water—and the noise spectrum is split up into frequency bands, each band being then suppressed in an *ad hoc* part of the detuner. The principal production detuners are the Mk V, for 5,000-7,000 lb thrust turbojets without afterburning; the Small Mk V, for 5,000-7,000 lb engines; and the Mk VI unit for the largest engines, with afterburning. These units have found wide acceptance in the British and foreign engine industries.

Dowty Fuel Systems, Ltd., Cheltenham, Glos, make complete gas-turbine fuel systems, with particular emphasis on the Spill-type burner. With this burner there is always plenty of fuel energy for good atomization; at high altitude, where the combustion flow is very low, the excess is spilt back from the burners and "goes round again." The delivery is regulated by the Dowty universal fuel governor which is insensitive to fuel density. One type of Ghost—that fitted to the NF.2 Venom—has a complete spill-flow system, complete with Dowty circulating pump and valve group which are all combined in one box. Dowty pumps have a great number of good features; it is worth noting that the

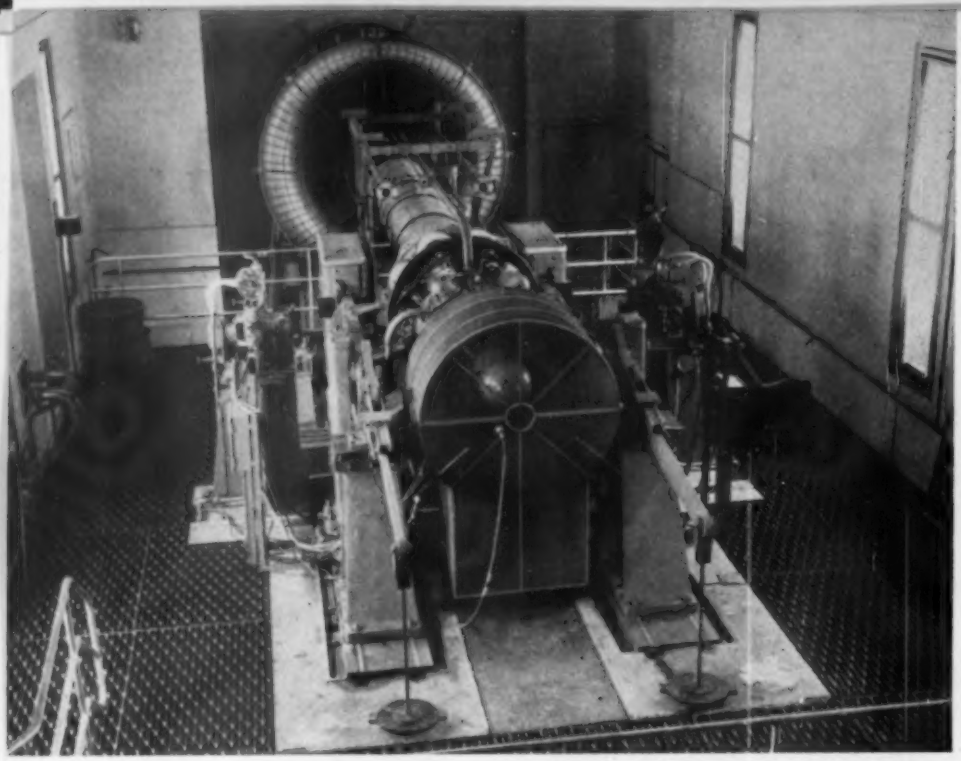
The assembly hall in the Stal factory at Finspong, Sweden, showing prototype Doverns being put together.

a system, much as was the case when separate combustion chambers were employed. The advantage is, of course, that power requirements are reduced.

Although tedious at times, rig and component testing should not be in any sense protracted. There is usually no question of endurance-testing at this stage, and once readings have been taken the test is complete.

As we have said, everything involved is put to the most severe tests, for operating requirements which are becoming progressively more arduous. By the employment of new techniques and higher temperatures, efficiencies are constantly being improved, but the higher temperatures create a great deal of trouble, not only for the engine designer, but also for the suppliers of such items as electrical equipment, hosings and lubricants. With turbine inlet temperatures now at about 1,100 to 1,200 deg K we are about at the limit to what can be done with present-day alloys. By employing blade cooling it is possible to add at least another 200 to 300 deg K, so opening the way to greatly increased

The rear of Pratt and Whitney's huge Willgoos turbine laboratory at Hartford, showing the concrete sluiceway down which cooling water flows back to the Connecticut river at a rate of 120,000 gal/min—nine times greater than the consumption of the city of Hartford.



A production Avon RA.7 on the test stand at the works of the Standard Motor Company, Banner Lane, Coventry. The engine is exhausting into a Detuner silencer.

The Quest for Power . . .

power from a given size of engine and, at the same time, improved combustion efficiency.

The split or two-spool compressor opens the way to increased output and efficiency through high pressure-ratio, and is altogether more flexible in its characteristics in that the two sets of rotating assemblies match themselves automatically when running. Although of increased mechanical complexity, such engines are in many ways easier to develop. As an example of this, it is evident that a two-spool engine can achieve a given high pressure-ratio with not much more than half the number of axial compressor stages that are needed by a single-shaft engine, and reduction in engine length is perhaps as important as reduction in diameter. But more than the usual number of bearings is needed.

Bearings, invariably of the ball or roller variety, may be obtainable "off the shelf." With modern speeds and loads, however, it is likely that the engine manufacturer will have to supply the bearing company (more than one as a rule) with data from which suitable bearings can be developed.

In a short time, the parts begin to come through for the first run of experimental engines. As soon as possible, one set is married up and the first prototype engine assembled and inspected. From now on, the engineers really have something tangible to work with, and it is largely a matter of making and breaking engines until the job is done.

The engine is mounted on a static test stand in a suitable cell—several cells are shown in accompanying pictures—and all connections for fuel, oil, air and electric power are made. The engine is then slowly motored over and, if all goes well, is run up to self-sustaining speed and the fuel turned on and ignited. Running is initially kept to low speeds with an oversize jet nozzle to maintain internal pressures and temperatures within moderate limits. After a short time, possibly only a few minutes to allow readings to be taken, the speed will be increased slightly. Succeeding runs will be of longer duration and at higher speeds until, if no trouble is met, full r.p.m. will be achieved. By this time, which may be a week or several months from the first run, a standard tailpipe will have been fitted and the engine will then be giving its design thrust.

But all kinds of trouble may have been met (although it is only extremely rarely that anything catastrophic occurs, for the mechanical properties of the engine should have been fully resolved long before this). At the first sign of trouble, or probably before, the engine will be "torn down" and subjected to careful scrutiny, initially visually or with gauges and micrometers, and later with X-rays, magnetic/fluid or fluorescent equipment, microscopes and any other inspection tools which the company may employ.

Much of the re-assembled engine—or more likely the second engine by this time—will be instrumented so that its behaviour can be closely watched. Dozens of thermocouples will be installed to measure bearing or gas temperatures, pitot traverses will indicate airflow, and strain-gauges will record mechanical behaviour, even on such inaccessible parts as the hot, high-speed turbine blading. The fully instrumented engine is then run under every condition that the establishment can reproduce. The results obtained will be the first to give a true picture of the engine, for it is impossible to produce accurate conditions on a test rig.

A long period of performance testing then begins, largely in runs of about two hours' duration. With luck, the design performance may be obtained straight off, but

ENG.129 pump, used on the Sapphire, has been retained for the American version of the engine, and is licence-produced by Thompson Products, Inc.

Drilube Co., 723 West Broadway, Glendale 4, California, market a new film lubricant "Drilube" for use where bearing pressures or temperatures are very high. It is a dry, flexible solid surface, bonded to almost any suitable prepared metal. Capable of use at 500 deg F, or 700 for short periods, it is employed in various "missile engines."

Dunlop Rubber Co., Ltd., Aviation Division, Foleshill, Coventry, manufacture a wide range of engine-accessory equipment. Electromatic valves and rams for piston-engine temperature control are well known, and operate at up to 3,500 p.s.i. For turbojets, Dunlop are important as suppliers of complete pneumatic actuating systems for afterburner eyelids, the Avon RA.7R, for example, having two Dunlop rams to each eyelid, with reducing valve, filter and two-piston, solenoid-operated valve. All these units can operate at 400 deg C. A wide variety of fuel-system flexible pipes is another Dunlop speciality, as is the provision of electrically heated de-icing equipment for engine intakes. Such de-icers are fitted to the Gannet and Viscount and, with an ice-detector, can be made quite automatic in operation, with cyclic or continuous heating. Dunlop are also marketing a number of grades of silicone rubber, most of which have been specially developed to meet the needs of the aircraft industry.

E.N.V. Engineering, Ltd., Hythe Road, Willesden, London, N.W.10, have precision gears and other specialized components in all types of piston and turbine power unit.

English Steel Corporation, Ltd., Sheffield, produce various gas-turbine steels with high temperature-and creep-resistance. From these steels, E.S.C. drop-forge turbine discs and shafts, which might be considered the most vital parts of any aircraft.

Equator Wheels and Sections, Ltd., Raglan Street, Wolverhampton, have turned out many thousands of stainless-steel stiffening bands for gas-turbine jet pipes. Rolls-Royce are among their principal customers.

Esso Petroleum Co., Ltd., 36 Queen Anne's Gate, London, S.W.1. At first glance the difficulties facing the producer of modern aero-engine lubricants may not be appreciated. The oil must remain pumpable at very low temperatures so that Arctic or high-altitude starts can be readily accomplished. It must not break down under enormous bearing loads—particularly in turboprop gear-teeth—and it must retain excellent properties under extremely high temperature conditions, and not oxidize or boil away. The whole set of requirements is so formidable that only one oil is currently cleared for use with the latest type of British gas-turbine—Esso Aviation Turbo Oil 35, which meets D.E.R.D. 2486. A parallel development is Esso A.T.O. 15 for American use.

Fel Electric, Ltd., 41 Sidney Street, Sheffield 1, make electro-magnetic crack-detection installations.

Firth-Derihon Stampings, Ltd., Tinsley, Sheffield, make drop-forged turbine discs, which go into such important engines as the Armstrong Siddeley Sapphire.

Firth-Vickers Stainless Steels, Ltd., Sheffield, supply the valuable 448 ferritic, stainless creep-resisting steel which is used for the turbine discs of the Avon, Sapphire and Olympus. Including fractions of vanadium, molybdenum and niobium, 448 steel has three times the rupture-strength required by the S.62 specification at 600/630 deg C, and 300-hr life.

Thos. Firth and John Brown, Ltd., Sheffield, are major suppliers of alloy and special steels for gas-turbine production.

C. J. Fox and Sons (Aviation), Ltd., 117 Victoria Street, London, S.W.1, market "Met-L-Chek," a quick and inexpensive method of locating metal-surface defects which is widely used in engine inspection. The procedure is the coating of the suspected part with two non-toxic fluids, bottles of which can be carried round in the pocket.

Funditor, Ltd., 3 Woodbridge Street, London, E.C.1, manufacture "Sand-jet" marking machines, which are used for marking parts in glass, ceramics, Nimonic and the hardest steels. Even on delicate blading this is a standard marking technique.

B. F. Goodrich Chemical Co., Rose Building, Cleveland, Ohio (Aero. Divn., Akron, Ohio), manufacture all kinds of rubber ware, including Hycar rubber products, and Electric Rubber—a heated sheet available down to one-twentieth inch thickness. The company's Industrial Products Division has also developed Pyrolock, a sprayed-on, quick-drying, heat-resistant coating for such items as rocket motor combustion chamber liners. A one-sixteenth-inch coat, which adheres well and resists corrosion, temporarily protects against temperatures higher than the melting point of the metal; a typical figure is 4½ sec on steel with a gas temperature of 5,000 deg F.

Garringtons, Ltd., Bromsgrove, Worcs, and Darlaston, Staffs, are manufacturers of forged blades for gas turbines, in stainless steels, nickel alloys, aluminium alloys, al-bronzes and titanium alloys. Especially for this work, the company has recently opened a precision forging shop with a larger production capacity than any other similar establishment in Europe.

General Electric Co., Schenectady 5, New York, are marketing a wide range of air-turbine driven accessories running on compressor-bleed air. Another line of development concerns electronic turbojet control systems; originally using thermionic valves in pressurized cases, temperature considerations have caused a switch to magnetic amplifiers, which appear to be satisfactory.

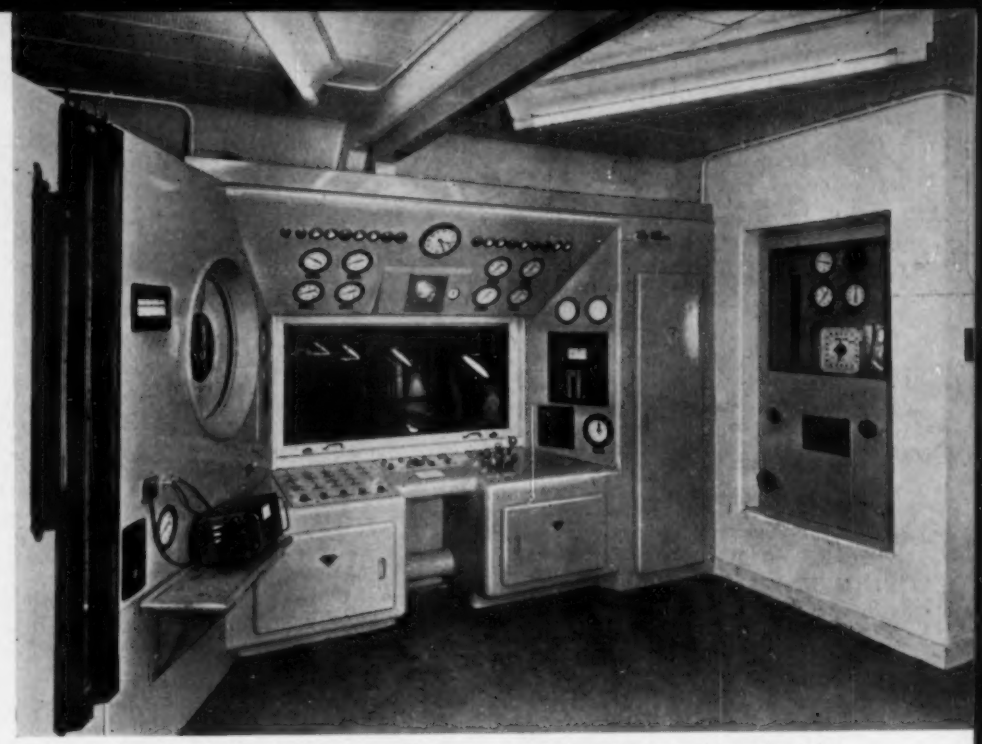
Joseph Gillott and Sons, Victoria Works, Graham Street, Birmingham 1, make precision pressings and are also noted for die steels with exceptional life, used for die blocks at Bristol for Proteus compressor blades.

Graviner Manufacturing Co., Ltd., Colnbrook, Bucks, last autumn announced the perfection of "Fire-wire," a continuous resetting fire detector which combines light weight, with extreme sensitivity, robustness and stability in operation. Breakage of the wire loop still leaves each semi-circuit working, and no amplifying valves are needed. Specified for T.C.A. Viscounts, Firewire is A.R.B. approved and has technical approval from the M.o.S.

H. M. Hobson, Ltd., Fordhouses, Wolverhampton, Staffs, have advertised their carburettors in this journal for over 40 years. They are now in volume production of a mass of fuel metering and injection equipment, engine-test devices, ignition controls, supercharger gear-changers and similar equipment. Unfortunately, little can be disclosed about their research, beyond the bald fact that they are at work on fuel systems for gas turbines, ramjets and rocket motors.

Hale, Hamilton and Co., Ltd., Frays Mill Works, Cowley Road, Uxbridge, Middx, specialize in fluid-control equipment, particularly pressure-reducing valves. Some of the more recent patterns can be used with either liquids or gases at pressures up to 6,000 p.s.i.

Hamilton Standard Division of United Aircraft Corporation, Windsor Locks, Connecticut, originally formed to design and manufacture airscrews, have now branched out into the realms of air-turbine drives, refrigeration systems, pneumatic engine starters, fuel systems and other fields. Their new research



A typical Heenan and Froude control panel; this one is governing an Avon cell at the Rolls-Royce establishment at East Rogerton, Scotland, where East Kilbride Avons are run.

three or four variations are often necessary in each of several parts of the engine. Mechanical loads are of little concern in this work, and in any case much of the performance testing is not arduous, for most of the time is spent in examining cruising or high-altitude conditions at about one-eighth full power. Temperatures will be recorded by thermocouples in many parts of the engine, some being scattered in the compressor airflow, others embedded in the metal of casings or blades; the blade thermocouples are cemented into drillings, and high-speed slip rings lead out the electrical signals, just as is done in strain-gauging.

Sheet-metal temperatures may be recorded by the use of special temperature-sensitive paints which are selected according to the range of temperatures expected, and applied to the part of the engine to be examined. A paint may, for example, pass through two or three distinctive shades within the range 920 to 990 deg K, remaining the final colour even after the engine has cooled. Also, a series of different colours on one component—e.g., a combustion chamber, give valuable evidence as to temperatures reached in various areas. With this technique, the engine is run for about a quarter of an hour, just long enough to stabilize the temperatures, without the risk of carboning or scouring the paint off. Airflow is measured by N.P.L.-type nozzles, pitot traverse combs, cascade rigs, mercury manometers or, for high pressures, bourdon gauges.

Some of the results are then sent to the calculating department so that the complex aerodynamic behaviour of the engine can be worked out. The General Electric Company at Lynn, in America, send these results through a direct teletype link to a battery of I.B.M. calculators many miles away in Ohio, and they get the answers back before the engine has cooled.

All this time the engineers know what the engine ought to do from their knowledge of the compressor, combustion and turbine efficiencies and compression ratio, which together indicate a certain design thrust equal to, or greater than, that required by the contract. At no point in testing is it possible to say "we're there"; the aim is to get as near to the design performance as possible—and, since the established engine companies are no mean hands at the game, they can usually get very close indeed quite quickly.

Performance testing may continue for some two years with everyone involved furiously busy the whole time. Total running time should be about 1,000 hours on each engine, including several quite lengthy runs. Total running time is a fair index of progress of the engine, although it should be carefully interpreted if a misleading conclusion is not to be drawn. Acceleration, shut-down, starting, thrust and general behaviour of the engine and fuel system will all be thoroughly examined, but some things cannot be done on the ground at the present time.

It is, for example, impossible for most companies to simulate true high-speed flight conditions, either at sea level or at high altitude. The high-altitude case is ruled out by the impracticability of exhausting the engine into a low pressure atmosphere, while the high-speed at sea level case, which imposes the greatest load of all, demands ram pressure supplies which are unobtainable without proper flight testing. Flight testing is also the only means of checking the behaviour of the engine under acceleration and gyroscopic loads.

One notable exception to these restrictions is the Swedish firm of Flygmotor, who enjoy a unique supply of compressed air which enables them to carry out test cell runs at full ram pressure as well as full-scale compressor testing with virtually no restrictions. In rock or clay 280ft below their experimental station they have blasted out large underground chambers which can be charged with compressed air at 120

The Quest for Power . . .

lb/sq in. This immense magazine holds no less than 130 tons of air at one filling, and the forces on its walls pose an interesting calculation. Valves release the air into any of a variety of test cells, the capacity of the magazine being so great that tests are rarely cut short by the supply pressure falling off.

Firms without such facilities can do no more than press on with ground testing until a flight clearance test has been successfully completed. Then, as rapidly as possible, the engine will be got into the air. A suitable test bed is a valuable asset; not only does the aircraft have to be big to hold all the equipment required, but it should be multi-engined so that it does not have to rely on an unproven power unit. A good ceiling is another requirement, and it is not inappropriate at this point to record how valuable is the Canberra for such work. It may be noted in passing that it is American practice to mount the test engine without ducting on a pivoted cradle attached to the belly of a large aircraft so that it may be swung out of the bomb-bay during test runs. This type of installation is illustrated.

Once in the air progress is accelerated rapidly. Not only is it possible to examine the performance of the engine at all speeds and altitudes and under all conditions of ram pressure and g loading, but it is possible to determine the handling of the engine from the pilot's point of view, so that provisional pilot's notes can be prepared.

Even in flight testing, the engine requires a prodigious amount of instrumentation. Not only will automatic observers be fitted to record all instrument readings photographically, but some results, such as those of strain-gauges, can be telemetered to the ground and there analysed or put on a tape recorder.

Flight testing is also the only means of proving fully the fuel and oil systems. Only in flight is it possible to assess their behaviour at high altitude, or under high acceleration loadings, and during dives and climbs and other critical periods. As for the engine itself, compressor stall or blade shedding may demand a hasty return to base, but huge test programmes can usually be completed in a few weeks of flying.

Ground testing then changes in character from an analysis of performance to sheer make-and-break endurance testing. This is generally resolved into a series of cycles, each of which includes a prescribed number of hours at selected ratings from idling to full thrust. These cycles are made more and more arduous until the company feel able to tackle the 150-hour M.o.S. acceptance test, which itself consists of such a series of cycles. The engine submitted for this test is carefully inspected by the M.o.S. preparatory to its test, and is then sealed in its cell to run without attention. Such tests are extremely expensive; the 150-hour run for a 30,000lb-thrust engine will involve the consumption of at least 350,000 gallons of fuel. The feelings of a company confronted with failure after 149 hours can possibly be appreciated.

The engine is now no longer experimental. Pilot production engines will be flowing through the shops and the manufacturer will probably be running from four to a dozen development engines at once, all of them different. This number will tend to increase for several years following.

Towards the end of endurance testing, if not before, the decision will have been

One of the first afterburners to see service; a reheat Allison J35 being installed in a U.S.A.F. Northrup Scorpion fighter.

laboratory contains such mighty facilities as a test chamber capable of taking a 20ft-diameter airscrew and running it at a simulated altitude of 100,000ft, and a test cell suitable for running 25,000 lb-thrust turbojets in the development of their fuel systems.

Hardy Spicer, Ltd., Witton, Birmingham 6, are renowned in many fields; in that of aero engines they make helicopter transmissions and the universal joints and drives connecting aero engines and remote accessory-drive boxes. It is, for example, a Hardy Spicer drive which couples the Comet 2's accessory boxes to the Avon 503s.

Heenan and Froude, Ltd., Worcester, is a very familiar name in connection with aero-engine test plant. They make all kinds of dynamometers, working on eddy-current, hydraulic or electric principles, as well as complete stationary or tilting wings for installed engine tests, torque and thrust measuring gear, hangar and wind-tunnel test stands, and other equipment. It is safe to assume that the Gyron, Conway, and all our other big engines, are being put through their full-scale tests with Heenan and Froude apparatus.

Heli-Coil Corporation, 248 Shelter Rock Lane, Danbury, Connecticut, have built up a large business out of small coil inserts made of stainless-steel, diamond-section wire, for acting as a bearing surface for bolts in threaded holes in softer metals. Using 18-8 stainless steel, with u.t.s. of 180,000 p.s.i., thousands go into American turbojets every week: the J40-WE-22 saves £6 per engine on compressor stator blade bushings alone; the forward frame of the J47 has 50 Heli-Coils whereas the later J73 has 306; and Allison have gone from 61 Heli-Coils in the J35-A-27 to 193 in later versions.

High Duty Alloys, Ltd., Slough, Bucks, not only make a vast quantity of airframe forgings—some with a 12,000-ton press—but they are one of the biggest suppliers of gas-turbine blading to a total of ten million blades in Hiduminium alone. They also make basic structural parts of several of our important engines; although one of the company's Hiduminium alloys is more usual, many such components are made in magnesium-base alloy. An example is the main air duct and inlet casing for the Double Mamba, which is a sand casting in Magnuminium 220.

High-Pressure Components, Ltd., 139 Kensington High Street, London, W.8, make "Gyp" couplings and connections used on the Proteus turboprop and many other engines.

Hughes-Johnson Stampings, Ltd., Langley Green, Birmingham, specialize in the more difficult forms of drop-forging, in all standard gas-turbine alloys, including titanium alloys.

I.V. Pressure Controllers, Ltd., Forge Works, 844 Bath Road, Cranford, Middx, make such things as full-bore line solenoids for gas or liquid services at pressures up to 4,000 p.s.i. These are available for B.S.P. from ¼in to 3in, 24 volts D.C. Other valves handle corrosive acids.

Imperial Chemical Industries, Ltd., London, S.W.1, are big enough to need a page to themselves; but in connection with engine manufacture it is appropriate to note the completion of development of their sodium hydride process, believed to be the only effective means of descaling titanium metal and the Nimonic alloys.

Industrial Engineering Co., Island Road and Suffolk Street, Philadelphia 42, Pennsylvania, have a compact Hydra-Brake which, mounted like an accessory on an engine-drive pad, can be used to provide an accurate measure of the power being delivered at the shaft. It is a form of water dynamometer, and the power is obtained by measuring the rise in temperature. A 1,000-h.p. unit is 14in by 10in, and weighs 35 to 55 lb.

International Nickel Co., Inc., 67 Wall Street, New York 5, supply alloys used in almost every American turbojet. Inconel is a basic wrought ni-cr-fe alloy, strong, heat- and corrosion-resistant, ductile, workable and without oxidation trouble at high temperatures. "S" Monel is a new extra-hard casting alloy, resisting galling and seizing at high temperature. A typical application is a turbine-shaft bearing cage, which runs dry for the first few seconds after the turbojet is started.

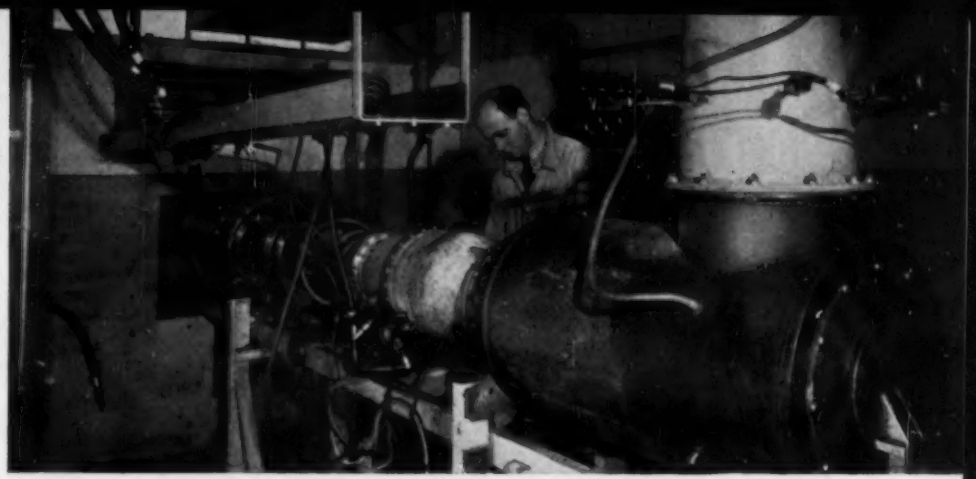
Jack and Heinz, Inc., Cleveland 1, Ohio, although initially specializing in electric starters, are now offering a great deal of other aircraft electrical equipment, including generators, inverters, motors, actuators and control systems. The company's electric starting equipment is fitted to the J33, J34, J42 and J47 turbojets, and many thousands of these engines are in use. But to meet the needs of bigger axial engines the company is developing a range of air-turbine starter motors. Another development is in the field of air-turbine-driven hydraulic power packs.

William Jessop and Sons, Ltd., Brightside Works, Sheffield. Before the comparatively recent change to ferritic materials, the Jessop austenitic alloy G.18B was very widely used for turbine discs—and is still in use on many early engines. More recently, however, Jessop H.46, a 12 per cent Cr ferritic steel has been developed. This alloy, which has a very high creep-strength, is used in production Avons and Sapphires, and in many new prototype engines. The austenitic G.56 combines good creep strength with very high proof stress, and should be of interest for particular applications. An 850-900 deg C blade alloy is G.42, and the even newer G.62 will be capable of operating at higher stresses and temperatures than any other blade material at present in production. Two other alloys are G.40 (with a minimum of strategic elements) and G.32 cobalt-base alloy. Nozzle guide vane alloys G.19 and 34 are now supplemented by G.39, which combines good casting with resistance to oxidation at 1,100 deg C and great resistance to thermal shock. Jessop's are also gaining experience with titanium, and have successfully produced compressor disc forgings, rings, sheet and other components.

Johns-Manville, Inc., Box 60, New York 16, who are associated with Delaney Gallay in this country, specialize in high-temperature applications. Their Goetze metallic gaskets, for example, are employed as hot gas seals and in afterburner igniter gaskets. J-M Tadpole tapes are used to seal firewalls and as gasketing tape for combustion chamber intakes, turbine flanges, and similar situations. Thermoflex felt, the basis of which is a lightweight heat-resistant RF-300 felt, is made up into precision tailored blanket for jet pipes, afterburners and, on occasions, complete engines. Some blankets have several layers of felt, gauze and reflecting foil, the foil usually being on the outside and resisting fluid attack.

K.L.G. Sparking Plugs, Ltd., Putney Vale, London, S.W.15, have made a great, if unspectacular contribution by the development of Hylumina, which is probably the finest high-temperature insulating material in the world. The K.L.G. Bluestone ceramic is incorporated in piston-engine sparking plugs and in such gas-turbine units as the K.R.200 igniter for re-heat Avons. Other K.L.G. products are complete thermo-couple harnesses, which are virtually standard on all British production engines; high-energy surface-discharge igniters for all kinds of turbojets and turboprops and high-frequency high-energy igniters, typical examples of which are those used by the Napier Nomad and the Plessey monofuel starters.

Kautex, Ltd., Elstree Way, Elstree, Herts, make "Neo-K-Tex" jointing material which, being proof against oil, petrol and water, finds numerous uses in gaskets, washers, sheets and mouldings.



Testing a scale model of an Avon afterburner on the thrust rig. Air comes down the large pipe on the right and passes through a Tay combustion chamber (at which the engineer is looking), simulating the supply from a real Avon.

taken upon the engine's future. If it is to go into production, the company will be charged with extensive tooling, and with the provision of materials and the conclusion of contracts with specialist and accessory suppliers. The latter companies will themselves have conducted their own tests on new starters, fuel pumps, systems and components—and possibly new materials—in parallel with the testing of the basic engine. Production techniques are outside the scope of this account, but it is relevant to point out that, if the engine finds wide military acceptance, it may require an output of compressor blades exceeding 20,000 per day. In this country, at least, the aim is the maintenance of reasonably flexible production, so that modifications can be incorporated with the minimum of disruption of effort; such modifications are invariably required after every run of 20 or 30 engines.

Long before the engine enters service, the manufacturer will be anticipating the needs of the operator in respect of overhaul life, spares provisioning, and the effects of constant servicing, such as repeated stripping and assembly. Requirements for fighter engines differ tremendously from those of a civil turbojet, but the indications are that modern gas turbine power units will have long lives and excellent overhaul times. In fact, it could be argued that they are too good for military service.

To be accepted, it is essential for a modern engine to be capable of real all-weather operation. For cold-weather tests, sites are being developed in high latitudes, generally on mountain tops; tropical conditions can be reproduced in this country fairly accurately by pre-heating the intake air—de Havillands, for example, have heated air with Goblin gas-producer sections before passing it to a larger engine under test. It is also possible that a water-methanol system will be necessary either as a means for restoring rated take-off power under adverse conditions, or as a power boosting system.

Normally, the engine will have been originally designed with a specific application in mind. According to this immediate installation the layout of the engine will be governed, not only to fit properly in the airframe, but also to render accessories and other portions readily accessible. For a wing-buried installation, the containing envelope is a rectangular box bounded by the ribs and upper and lower skins. The best place for the engine accessories is therefore on the "bottom corners" at five and seven o'clock seen from the front, where they are accessible through doors in the lower wing skin without projecting beyond the boundaries of the engine bay. Other excrescences which require less attention, such as cabin air bleeds and hot-air ducts, can occupy corresponding positions on the upper half of the engine. If the engine is to go in a circular-section fuselage, a drive shaft may be necessary for an accessory gearbox in front of the engine; alternatively, the gearbox can be mounted some distance away and powered by a turbine driven with compressor bleed air. Yet more advanced solutions are in prospect.

This practice of bleeding air from the compressor is becoming increasingly widespread, and has to be taken into consideration in the initial design of the engine. Flows equivalent to several hundred horsepower are now being tapped off really big turbojets, to provide cabin pressure, auxiliary power, protection against icing and, in conjunction with expansion turbines and heat exchangers, refrigeration. It may be noted that, if all the air is bled off at one point, the compressor delivery is not uniform around the combustion space, and it is better to drill several holes around the periphery of the compressor case and attach a circumferential manifold. Light-alloy ducting was once used to take the air away, but this breaks down with the hot air from modern engines, which require stainless steel.

Shaft drives for accessories can usually be provided along any of the streamlined radial struts in the intake to the engine, and the aircraft designer is often left to select which strut or struts is used. The design of the engine may also to some extent be influenced by the type of starter fitted. Apart from the fact that the starter drive may be in a variety of places—in a two-spool engine, for example, it will probably be in the middle of the engine, driving the high-pressure assembly—starter power sometimes requires "beefing up" of parts of the engine beyond the strength needed for normal running. This is particularly true of British fighter engines, for which a ten-second starting cycle applies. The combustion starters needed by this requirement may have to deliver 200 or 300 h.p. at high torque within a second or so of the pilot pressing the button.

These considerations clearly affect the engine manufacturer, and there is a host of

The old and the new: the single Pratt and Whitney J57 turbojet in the foreground develops roughly the same power as can all the seven R2800 Double Wasps lined up in the rear.

The Quest for Power . . .

other fields in which the airframe company is also concerned, including fuel, oil, electrical and ignition systems and, if such equipment is fitted, an automatic engine-control system. The last-named can be electro-hydraulic, or of an electronic nature, the latter probably using magnetic amplifiers. These control systems are particularly necessary where an afterburner is fitted, so that fuel flow, r.p.m., jet-pipe temperature, and nozzle area can all be inter-linked automatically.

Afterburners themselves—or reheat jet-pipes, as they are sometimes known in this country—are generally accepted for increasing the performance of high-speed fighters. Basically, these devices are just enlarged tailpipes attached to the rear of the engine, within which additional fuel can be injected and burnt. The basic configuration may take several forms, according to the degree of augmentation sought. Generally, a diffuser section is attached directly behind the engine tail-cone, with fuel injection nozzles and flameholders at the point of maximum diameter; some of the theory involved is briefly discussed in the section on ramjets, which follows later.

Since the mass-flow, temperature and gas pressure may all be increased by reheat, it is essential to have a larger propelling nozzle than is needed by the basic engine. If the nozzle were kept the same size, the internal gas pressure would rise dangerously and, as the flow through the turbines is subsonic, would be transmitted forward to ruin the performance of the engine. On the other hand, an afterburner is essentially a boosting system for intermittent use, and considerable thrust-loss would result if an enlarged nozzle were permanently fitted. Accordingly, the nozzle area has to be made variable, most current systems employing a pair of "eyelid" shutters moved by a mechanical actuator.

Owing to the tremendous flow of very hot gas through the afterburner, it is very difficult to carry out full-scale testing of a new design, and the initial development will be done with models; it is common practice to use a model of about one-third scale,

Laycock Engineering, Ltd., Victoria Works, Millhouses, Sheffield 8, make "Layrub" vibration-resistant transmissions which run without lubrication or metal-to-metal contact. A typical example is the drive between the Britannia accessory gearbox and the driving Proteus turboprop. The company also state that the production Seamew will be powered by a Mamba 6, from which a Layrub coupling will drive accessories.

Leytonstone Jig and Tool Co., Ltd., Liverpool Works, High Road, London, E.10, are major suppliers of jigs for engine production; their jig castings are widely used in the manufacture of nearly all British power units.

Lodge Plugs, Ltd., Rugby, have served the British Aero engine industry for 50 years. Their present products include gas-turbine igniter plugs and piston-engine sparking plugs—all with Sintox insulators—and screening and testing equipment. Lodge LR102/1 igniter plugs are found on the Avon RA.7, and a pair of Type 433 flame igniters is used to light up the Olympus.

Low Moor Alloy Steelworks, Ltd., Low Moor, Bradford, Yorks, make all kinds of gas-turbine steel and, in conjunction with their associated company, Low Moor Fine Steels, fabricate these alloys by a number of processes. Of exceptional importance is the French Ugine-Séjournet process for extruding stainless steel, using glass as a lubricant; the company hold the English rights. By this means, gas-turbine rings and flanges can be made from wrapped-around extrusions, which is proving more satisfactory than cutting off lengths of centrifugal casting.

Joseph Lucas (Gas Turbine Equipment), Ltd., Birmingham and Burnley, are responsible for the design and production of the complete fuel system, burners and combustion chamber of the majority of British gas turbine aero engines. Their fuel pumps, which operate at up to 4,000 r.p.m. yet are lubricated only by the fuel, can deliver various flows at pressures of 2,000 p.s.i. For this work finish tolerances of the order of 2 micro-inches are required. Various fuel systems are in production for low, medium and high-altitude flight. An advanced type of pump is that which, driven by a tiny turbine running at 24,000 r.p.m. on compressor bleed air, supplies fuel to a turbojet afterburner with a combined flow-rate and pressure of 2,000 gal/hr at over 600 p.s.i. Progenitor of a large family is a combined fuel control unit for expendable turbojets which, in a simple and compact form, embodies an altitude control, proportional-flow throttle valve, spill valve and shut-off cock. A particularly neat device is a gas-temperature control unit, the sensing head of which (mounted downstream of the turbines) has quartz and steel rods end-to-end so that differential expansion actuates a bleed valve which, in turn, reduces the fuel flow to restore the optimum gas temperature.

Magnesium Elektron, Ltd., Clifton Junction, Manchester, make a great contribution with "Elektron" magnesium-zirconium alloys, which enjoy a unique combination of low specific gravity, pressure-tightness and high creep-resistance. In countries producing British engines under licence many foundries are turning out Elektron alloys with the permission and assistance of the Manchester company. Magnesium-zirconium-zinc-thorium alloys ZT1 and TZ6 are now in wide use, particularly in the manufacture of the very latest high-pressure turbojets.

Manchester Oil Refinery, Ltd., Trafford Park, Manchester 17, market "Lumor" and "Glomor" for the fluorescent detection of cracks. The suspected part is painted with the appropriate ink and, after allowing about one minute's drying, is examined in ultra-violet light. Surface cracks are revealed by brilliant green fluorescence.

Manganese Bronze and Brass Co., Ltd., Elton Park Works, Hadleigh Road, Ipswich, manufacture "Oilite"

self-lubricating bearings and washers, precision - made by powder metallurgy.

Marston Excelsior, Ltd., Fordhouses, Wolverhampton, an I.C.I. subsidiary, supply several types of fuel tank, as well as all types of heat-exchanger. Some of the latter are brazed light-alloy units able to work at high pressures and temperatures.

Metalastik, Ltd., Leicester, have long been famous for their vibration-isolating engine mountings employing rubber bonded to metal. The various types of mount by no means follow a set form, as is shown by comparing the Metalastik units of the Dove, Heron, Shackleton and Comet. The company is now involved in various advanced developments, and are using silicone rubber in some products, to meet arduous temperature limits.

William Mills, Ltd., Friar Park Foundry, Wednesbury, Staffs, mass-produce high - quality aluminium-alloy castings, a typical example of which is the complex-shaped diffuser and expansion chamber that forms the front half of the Ghost combustion chamber.

B. O. Morris, Ltd., Briton Road, Stoke, Coventry, well-known for their "Morrisflex" range of flexible-drive abrasive and polishing equipment, have—in conjunction with the Bristol engine division—developed a very simple method of finishing off all types of gas-turbine blading to the correct edge radius.

D. Napier and Son., Ltd., Acton, London, W.3, have developed a lightweight, sprayed-on electric heater mat which was recently described in this journal. It is used to heat the intakes to the turboprops of both the Gannet and Seamew.

Omes, Ltd., Beverley Works, Barnes, London, S.W.13, are designers and manufacturers of machinery for producing closely controlled, electro-upset forgings from bar stock, the upset being formed from an exceptional number of diameters of stock by a combination of resistance heating and hydraulic pressure. Omes are also in volume production for the aircraft industry with this method, one of the largest single items being the manufacture of gas-turbine blading in all standard materials. At the last S.B.A.C. show the company also showed its prowess with titanium.

S. E. Opperman, Ltd., Stirling Corner, Boreham Wood, Herts, make precision gears and drives, many of which are found in our latest gas-turbines.

Pesco Products Division, Borg-Warner Corporation, 24700 North Miles Road, Bedford, Ohio, believe they have fuel and other pumps on every American jet aircraft. They employ a special pressure-loading to reduce leakage and take up wear; the largest pumps deliver about 5,000 gal/hr.

The Plessey Co., Ltd., Vicarage Lane, Ilford, Essex, make a wide range of aircraft products including all kinds of pumps, valves and oil-separators, complete screened ignition harnesses, wiring systems and actuators. But their chief power-plant interest is the production of starters, of electric, cartridge and liquid monofuel types, the latter—using iso-propyl nitrate as fuel—being particularly advanced in conception and development. The company is now also manufacturing fuel/air starting equipment, for some of the largest British gas-turbines.

Precision Rubbers, Ltd., Bagworth, Leicestershire, make a wide range of aircraft products including "O"-ring seals to finer dimensional tolerances than British or American standards; diaphragm fabrics in natural and synthetic rubbers, based on Nylon or glass cloth, together with Silicone mouldings, extrusions and sponge parts. Another series of products is a range of special protective lacquers and synthetic-oil-resisting paints.

Pulsometer Engineering Co., Ltd., Nine Elms Iron Works, Reading.

supplied with exhaust from a single turbojet combustion-chamber. The performance of this model will be studied in the usual manner (for pressure drop, temperature distribution, resonance and similar parameters) and, when something approaching the optimum has been determined, testing may continue with fuel nozzles and flameholder in place. A full-scale afterburner will then be made, the material being heat-resistant steel sheet, possibly with some ceramic or ceramel parts in the hottest regions, and the main body will be entirely welded to tolerances very much closer than usual for this size of sheet metal work. Stressing is largely dictated by internal gas-pressure and the general need for robust construction, but some American afterburners are so designed as to be capable of being cantilevered from the rear of the engine without additional support, to permit inspection of the engine by removal of the complete rear fuselage and tail.

Ground runs are then carried out with the afterburner connected up to the turbojet for which it was designed, and very considerable time will be spent in obtaining optimum fuel atomization and combustion in the smallest possible volume. Clearly, if the whole unit is too big, it will spoil the shape of the rear fuselage into which it will eventually fit. Particular attention will be paid to behaviour under conditions of low pressure at high altitude, for it is here that combustion is most difficult.

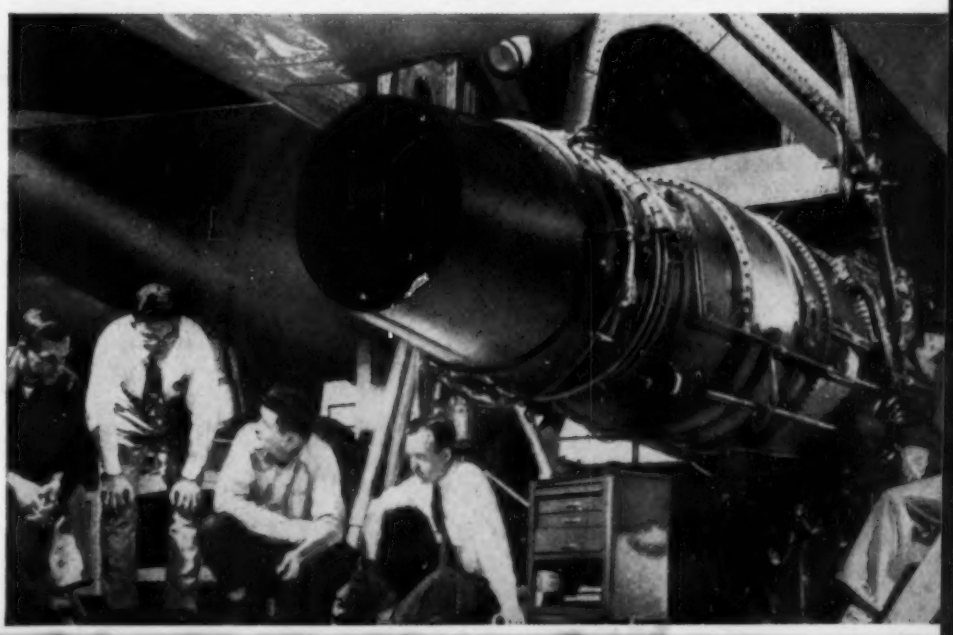
As soon as the company feel that they are near to the optimum performance, the reheat engine will be installed in a high-speed aircraft, preferably a machine capable of high-altitude flight. Development trials frequently take place with a propelling nozzle fixed at the area required by afterburning so that the basic unit can be fully developed before complicated nozzle mechanisms are worked out. Unfortunately, while highly efficient for the reheat case, this results in some loss of thrust when the turbojet is working alone, a fact which may lead to an exceptionally lengthy take-off run. Thus, a 12,000 lb-thrust engine with a fixed-area afterburner nozzle fitted might give 18,000 lb thrust with reheat on, but only about 9,500 lb thrust with the engine working alone.

The development of nozzles and flameholders poses similar problems to those met in the development of ramjets, as discussed later. The afterburner fuel system is a matter requiring much thought for, owing to the absence of any restriction such as a turbine on the maximum gas temperature, it is possible to burn enormous quantities of fuel. A modern afterburner may require as much as 3,000 gal/hr, and some companies employ remarkably compact little pumps driven by compressor-bleed air turbines.

TURBOPROPS. Contemporary gas turbines spin much faster than the airscrews which they drive, and a gearbox is therefore necessary, with a ratio between 5 and 10:1. It might be thought that the design of a fixed-ratio gearbox would be straightforward, but in practice this has proved a source of problems which at times have appeared almost insoluble. When it is appreciated that the turboprop requires a control system interlinking airscrew pitch, fuel flow, r.p.m. and other parameters, to permit efficient operation under all conditions, including rapid acceleration and reverse pitch for braking, it is seen that the turboprop has all the problems of the turbojet, and some special ones of its own.

Generally speaking, the gearbox is the worst nut of all to crack, and the design of this component is got under way as soon as possible. Long before the gas-generating part of the engine is running, back-to-back testing of gears and complete gearboxes will be under way. Many of the earlier gearbox troubles arose from a simple lack of appreciation of basic principles, owing to the fact that these had never before been required in practice. For example, meshing rates of thousands of teeth per second had to be accepted, and the slightest irregularity in tooth position or profile resulted in enormous acceleration on the tooth face. Tooth loadings were in any case exceptionally high, as can be determined by

American ideas: General Electric's large new J73 turbojet mounted for flight testing under a Boeing B-29 four-engined bomber.



The Quest for Power . . .

consideration of a 3in gear transmitting 6,000 h.p., even if the r.p.m. are as high as 10,000. Tooth deflection, therefore, has to be taken into account.

Not only the teeth themselves but bearing-cages and similar items have been prolific sources of bother, many of the failures occurring only after a considerable period. Cures have sometimes meant complete re-design of the defective part, but a change in material or surface finish has also proved effective. It must also be noted that tooth scuffing and general breakdowns might still be met were it not for the development of really good lubricants, suitable for the heavy loads and high heat-dissipation requirements of turboprop gearboxes.

Development of the gas-producer section (compressor, cans and turbine) can go ahead fairly normally, and once the gearbox has been got roughly into shape, a complete engine can be put together and run as a unit. Component testing can possibly be more flexible and accurate, but it is only sheer hard test-bed running that can uncover mechanical troubles and really probe the engine as a whole. Fuel system, clearances, seals, temperatures and vibration all need genuine running; and when a part breaks it is replaced and the engine re-started if this is humanly possible.

Free-turbine engines, in which the airscrew reduction gear is driven by a separate turbine mechanically independent of the rest of the engine, are more flexible in behaviour than single-shaft engines; in particular, the gas-generator section finds its optimum speed and is not prone to stalling, or being otherwise hindered by what the airscrew is doing. The latest turboprops are, as might be expected, split-compressor axial engines, in which the combination of high pressure-ratio and low mean propulsive jet velocity should offer very competitive fuel consumption. In such engines, it is probable that the airscrew will be driven off the front, or low-pressure, compressor.

Some types of turboprop require a brake to stop the airscrew from spinning in the wind when the aircraft is parked. A shaft drive for the accessories is also a requirement, and the mass-flow of most turboprops now in service is too low to permit much bleeding-off of compressor air. For naval use, it is essential that the pilot has full power rapidly available to enable him to overshoot following a "wave-off"; Armstrong Siddeley engines for the Royal Navy are all of the constant-speed type (the Double Mamba stays at 14,500 r.p.m.), and the thrust can be rapidly varied by control of airscrew pitch.

Comment is also worthwhile on the same company's recent turboprop bearing developments. Originally, air-cooled main bearings were fitted with an enforced fixed consumption of expensive synthetic oil. The trend is now towards fully-scavenged oil-cooled bearings with scroll seals and fluid feed lubrication by bulk oil (no air) from a jet at 40 lb/sq in. The scavenge oil is fed straight back to the main reduction gear, which is employed as a de-aerator, loss of oil being prevented by maintaining a high ambient air pressure around the bearing. The new arrangement has much greater cooling capacity and greatly reduces oil consumption.

The mechanical strength of a turboprop has to be high, to enable it to stand all the loads imposed on a turbojet as well as considerable torque and gyroscopic loads from the airscrew, and the cantilevered weight of the airscrew and reduction gear. Pick-ups on the engine and the casing itself have to be very strong if these loads are not to cause dangerous reductions in compressor-blade clearances, particularly during heavy deck-landings. But such problems can be seen and anticipated; what really takes time in turboprop development is perfection of the fuel, airscrew, and control system.

In the years to come, it is faintly possible that the development of supersonic airscrews may, coupled with power turbines of a size suitable for r.p.m. not exceeding about 4,000, make it possible to dispense with the reduction gear. At present, however, very great problems stand in the way of this happy state of affairs.

At this point, it is appropriate to say something about the by-pass engine, though it is difficult to do so without revealing too much of Rolls-Royce design-thinking. Suffice to say that the engine can be considered as a two-spool gas turbine with an oversize low-pressure compressor, the excess delivery from which is by-passed around the combustion chambers and turbines to form a comparatively cold, slow-moving flow, blanketing the hot, high-velocity central jet. Compared with a turbojet, the reduced mean jet velocity of the by-pass engine will mean increased propulsive efficiency, and quietness in operation may also be attained. But engine diameter will clearly be on the high side, and it is therefore surprising that the only announced application of such an engine—the Rolls-Royce Conway—is a wing-buried installation. The development of this engine will obviously be more than usually involved from the thermodynamic, aerodynamic, mechanical and maintenance aspects; but Rolls-Royce probably have all this behind them. Mr. G. R. Edwards, of Vickers-Armstrongs, who is not a man given to backing the wrong horse, has said "we know that the Conway works."

PISTON ENGINES. Unlike all other basic types of aero engine, the piston engine is no longer being developed from scratch except in the smallest sizes; an exception, of course, is the Napier Nomad, which is very much a special case. Today, work on piston engines is predominantly a process of consolidation, with the accent on increasing the overhaul and ultimate life.

Generally, the process is governed by a series of regular meetings, at which all service failures or operator's suggestions are analysed and sorted into groups, and the resultant trend—if any—noted. Thus, the behaviour of thousands of roughly similar engines will be examined from such standpoints as fuel-injection system, ignition, valve

Berks, produce a wide range of fuel-handling equipment. One of the latest airborne units is an air-turbine-driven pump capable of passing 3,500 gal/hr. Forty types of aircraft fuel and booster pump are marketed, capable of handling petrol, kerosine, water/methanol or diesel oil. They have been used with high-octane fuels up to 50,000ft under favourable conditions.

The Pyrene Co., Ltd., 9 Grosvenor Gardens, London, S.W.1, have developments in all fields of fire detection and suppression. Examples are CO_2 duo-head, "wet water," pistol-grip and methyl bromide extinguishers, and smoke detectors and visual smoke indicators.

Pytram, Ltd., Dunbar Road, New Malden, Surrey, supply, *inter alia*, seamless ducting capable of accepting air at from −70 to 200 deg C.

R.P.R. Patents, Ltd., Alexandra Palace Station, London, N.10, are responsible for the Sempun magnetic flaw detector, an ingenious and easily portable device now in use by Government departments, aircraft and engine manufacturers, and others.

Ragosine Oil Co., Ltd., have formed a subsidiary, Racol, Ltd., Ibex House, Minories, London, E.C.4, to market their anti-scuffing pastes, molybdenized lubricants, core-locking compounds and other products of this nature.

Ransome and Marles Bearing Co., Ltd., Newark-on-Trent, co-operated in the supply of bearings for the very earliest British jet engines, and their products have been in many engines since.

Rellumit (London), Ltd., Chandos House, Palmer Street, London, S.W.1, are a branch of a French firm who specialize in micro-filters. A wide range is offered, with particular emphasis on gas-turbine requirements, including test-rigs and bulk storage installations.

Reynolds Tube Co., Ltd., Tyseley, Birmingham, noted for seamless steel tubing, make the precision welded engine mountings for the Merlin, Leonides and Centaurus 661, the latter not being of circular section. Other products include pressure vessels and stainless-steel rings for gas turbine engines.

Robert Riley, Ltd., Milkstone Spring Works, Rochdale, Lancs, make springs in all standard materials, including beryllium-copper.

Rotameter Manufacturing Co., Ltd., 602 Purley Way, Croydon, Surrey, describe themselves as specialists in instruments for liquid and gas flow measurement and control. The vertical-scale flow indicators of engine test-stands are usually Rotameters.

Rotax, Ltd., Willesden Junction, London, N.W.10, one of the world's largest manufacturers of aircraft electrical equipment, are also making a wide range of electric, solid-cartridge, liquid monopropellant and petrol/air starters for all types of engine. Interest centres chiefly on the turbine starters, three of which are: (1) Solid propellant Type CT.0101, two-shot unit weighing 60 lb, and designed originally for the Venom Ghost turbojet; it delivers 137 h.p. at 8,450 r.p.m., and has a torque on the output shaft of 90 lb-ft. (2) Iso-propyl nitrate starter, developed for large axial engines, the starter unit weighing 60 lb. (3) Bendix-developed petrol/air starter used on some types of Sapphire, weighing 70 lb. On the Sapphire the acceleration time from rest to 2,000 r.p.m. is about 3½ secs, for air and fuel consumptions of 3.8 lb and 0.275 lb per start.

Roto-Finish, Ltd., 39 Park Street, London, W.1, have developed a "Rotofinish" process, with various chips and compounds, which is now in regular production on high-speed gears and turbine blading.

Rotol, Ltd., Cheltenham Road, Gloucester, for long one of the biggest airscrew manufacturers, are now

widening the scope of their activities considerably. One very large line of development is the design and production of remote accessory gearboxes which, driven by a shaft from the main aircraft power unit, have mounting pads for any desired assortment of ancillary-power units. Examples are the gearboxes of the Gannet and Comet 2. Rotol now have an agreement with the AiResearch company, under the terms of which they can make use of the American company's experience in the design and production of air-turbine drives for such gearboxes; the first such unit by Rotol mounts a 15 kVA alternator and a 3 kW generator. Yet another aspect of Rotol work is the development of synchronising units which precisely interlink the r.p.m. of any number of piston or gas-turbine power units. An example of this equipment is being built into each T.C.A. Viscount.

Rubbaglas, Ltd., 245 Vauxhall Bridge Road, London, S.W.1, produce a variety of forms of rubber/glasscloth, including Rubbaglex. This has a number of valuable characteristics, including good mechanical properties, high resistance to general weathering and proof against aromatic hydrocarbon fuels, kerosine, hot engine oil (D.T.D.109) and various solvents. Rubbaglex S.L.C. silicone and Silastic rubber-processed glasscloth is also available.

Ryan Aeronautical Co., Lindbergh Field, San Diego, California, were pioneers in the ceramic coating of high-temperature parts. In the first half of 1952, a subsidiary—California Metal Enameling Co.—was delivering over 12,000 exhaust and jet parts monthly with ceramic coating; the Wasp Major four-row radial exhaust assembly involves larger stainless-steel stampings than ever before attempted, with new techniques in forming and welding. Now Ryan are engaged in volume production of ramjet and rocket assemblies.

Geo. Salter and Co., Ltd., West Bromwich, Staffs, supply all types of springs, retaining rings and circlips, and also make roller bearings.

Joseph Sankey and Sons, Ltd., Albert Street, Bilston, Staffs, have long been renowned for their precision sheet-metal work, and gas-turbine parts form a high proportion of their output. Many famous engines, including the de Havilland Ghost, have Sankey stainless-steel combustion chambers, flame-tubes, support cones and tailpipes. Expansion bellows and heat exchangers are other Sankey products.

Saunders Valve Co., Ltd., Aircraft Division, Blackfriars Street, Hereford, are probably the world's best-known suppliers of aircraft spherical plug cocks. Their range, with triple-diaphragm sealing, gives glandless, full-bore control of fuel, oil, oxygen, water/methanol, nitrogen and other fluids.

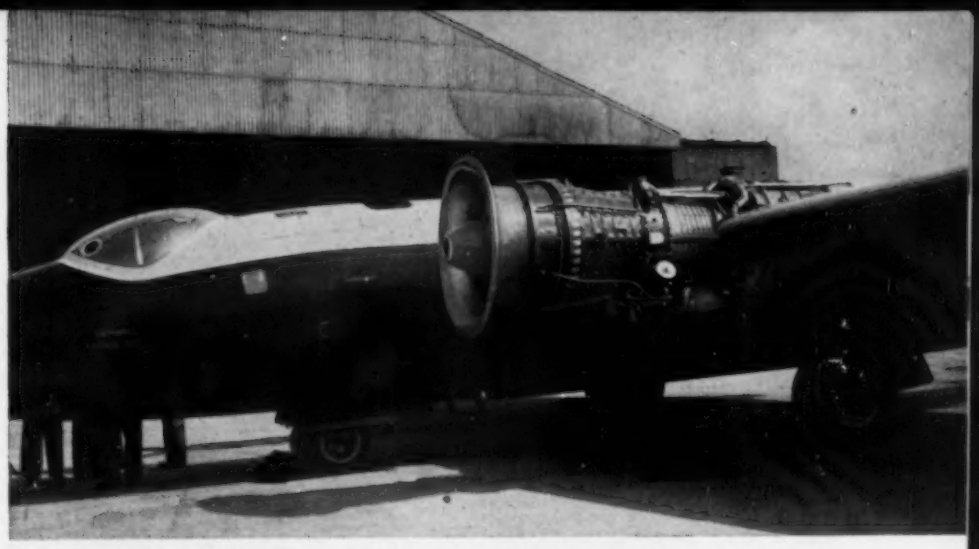
W. Bryan Savage, Ltd., Westmoreland Road, London, N.W.9, are one company making special low-radio-frequency amplifier equipment for gas-turbine-engine fatigue testing.

Self-Priming Pump and Engineering Co., Ltd., Slough, Bucks, have fuel pumps of all sorts on the fastest aircraft. Type 1607, for an aircraft which has yet to fly, is exceptionally neat and delivers up to 1,600 gal/hr off a 24-volt system. Other S.P.E. pumps are found on Canberras, Mystère IVs, and Gannets.

Shell-Mex and B.P., Ltd., Shell-Mex House, London, W.C.2, have kept abreast of every new aero-engine development and have had the right fuel and lubricant available at the right time. An important contribution to this work has been made by the company's research laboratories at Thornton-le-Moors, Cheshire.

Skefco Ball Bearing Co., Ltd., Luton, have many ball and roller bearings in piston and turbine engines.

Smiths Aircraft Instruments, Ltd., London, N.W.2, make many



Bristol's two-spool Olympus mounted in the Canberra which at present holds the world altitude record at 63,668ft. It may be added that the ground-test intake cone was not fitted at the time.

gear and bearings. Trouble never seems to come singly in aero engines; after years of service a whole crop of similar failures is experienced, and the manufacturer's task is to decide at what point it becomes necessary to introduce a modification.

Such action is not taken lightly, for it will involve possibly thousands of engines owned by hundreds of operators all over the world. It has also to be determined whether, if a new part is produced, it will be generally ordered. It may also be that the fault will lie with an accessory manufacturer. In any case, the engine company has to keep a number of piston engines running on test to prove such modifications—and, as this is rarely the subject of a development contract, it is paid for by the engine company. This continuous development continues until the last engine goes out of service.

PULSEJETS. These noisy little tubes are closely akin to organ pipes, and the natural resonant frequency of their contained air is used to provide thrust. The air enters through a system of flapper valves at the front, the frequency of which is matched to that of the tube. Fuel is injected and ignited, and the rapid rise in internal gas-pressure then closes the inlet valves, while the exhaust escapes rapidly from the open end of the pipe. The momentum of the jet gas then creates a depression inside the duct, which permits the ram air at the front to re-open the valves and refill the engine. The cycle is then repeated, the residual pockets of hot gas from the previous cycle being used to fire the combustible mixture of the second. The frequency can be varied by altering the pressures and temperatures involved, and also by changing the length of the duct.

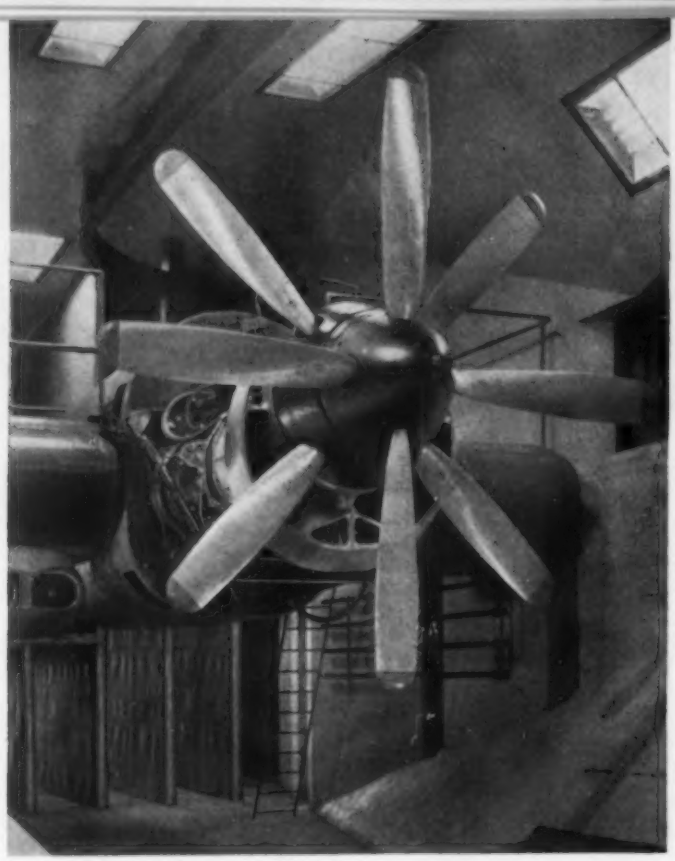
Development thus centres upon finding the right front-end arrangement of intake and valves, and the optimum pipe-length. Combustion has to be rapid for full pressure-rise to be attained, and volatile fuels such as propane may be employed, perhaps with special additives. Valve life is a thorny problem, and 50 hours is about the limit that can yet be achieved. For helicopter tip-drive, the unit must be made strong, so that it will hold together under vibration and centrifugal loads; and it is also essential to have a properly controlled gas-flow and flame-distribution, to avoid local "hot spots" on the duct wall. The applications of pulsejets are clearly limited both by speed and altitude, and appear at present to be restricted to small helicopters.

RAMJETS. These are the "fastest" of all air-breathing engines. Essentially, both the engine and its principle of operation are simple, although the design (and, to some extent, manufacture) is not. Basically, a ramjet can be likened to an afterburner or, alternatively, to a turbojet with the rotating assembly removed.

As the flight Mach number of a turbojet is increased, the pressure-ratio of the compressor falls, eventually reaching a theoretical value of unity, i.e., the compressor is merely heating the intake air. In such a condition, the compressor and turbine can be removed without affecting performance and, owing to the easing of restrictions on maximum gas temperature, fuel flow and hence thrust can be increased. The result is a ramjet.

At the front, a suitable intake leads air into a diffuser section of steadily increasing

French development: a Dassault Ouragan being fitted with a Hispano Suiza Nene with afterburner preparatory to flight testing. This afterburner is quite clearly not capable of being cantilevered.



A Double Mamba on a test-bed at the Armstrong Siddeley factory; the engine is mounted on a non-lifting wing in a tunnel fitted with silencing splitters at both ends.

The Quest for Power . . .

diameter, in which the pressure of the airflow rises at the expense of velocity and Mach number. At the rear of the diffuser, pressure is sufficiently high and velocity low enough to permit the maintenance of stable combustion; the fuel is injected from a nozzle array and the flame held in the airstream—which is still roaring through the engine at high speed—by a flameholder, which is a carefully designed baffle capable of producing a local region of slow-moving turbulence without much loss in total-head pressure. The hot exhaust gases are then expelled through a propulsive nozzle, and the thrust results from an unbalanced longitudinal force on the inner wall of the diffuser. Such is the ramjet, and there is much more to it than the unfortunate appellation "stove-pipe" would suggest.

It is a power unit that appears to have been sadly neglected in this country, although many well-known firms are now devoting attention to it. Its applications are widespread. It is suitable for a speed range from Mach 2 until the so-called "heat barrier" rears up at about Mach 6. Primarily of interest for guided-weapon propulsion, the ramjet is also seen as a booster and possibly even a primary power unit for manned intercepters. It is also likely to be of use in the tip-drive of supersonic helicopter-rotors, and it can also be combined with a rocket in a variety of ways, generally with the rocket mounted within the ramjet to help it take-off and to keep the flame alight at very high altitudes. The subsonic ramjet is attractive only on account of its low weight and simplicity, but has already been extensively used for helicopters and target aircraft.

Assuming the requirement is for a large ramjet for a long-range missile, the company will back-up a large amount of paper work with the usual rig-testing of models and components. This work will differ from that involved in turbojet development in two main features: the enormous power required will make full-scale ground testing impossible, and an unusual amount of attention will have to be paid to the fuel and control systems. One hypothetical Marquardt ramjet, intended for a ground-to-air weapon designed to cruise at Mach 3 at 80,000ft, has a diameter of 30in and a weight of 1,260 lb. Calculations show that, at the end of the boost phase after six seconds of rocket-assisted flight, the design Mach number of 3 will be reached, and the following data apply: h.p., 370,000; airflow, about 1,000 lb/sec; fuel consumption, 45 lb/sec; stagnation air temperature, 1,100 deg F; and stagnation air pressure, 260 lb/sq in absolute. At the cruising height of 80,000ft these values become: speed Mach 3 (reduced from 2,210 to 2,000 m.p.h.); h.p., 2,000; airflow, about 6 lb/sec; fuel consumption, 0.27 lb/sec; stagnation air temperature, 780 deg F; and stagnation air pressure, 10.5 lb/sq in absolute. The dominant factor revealed by these figures is the enormous variation in operating conditions for which the engine has to be designed; the fuel flow, for example, varies by 165 : 1.

A plain, open-mouthed intake with a normally attached shock-wave involves an unacceptable loss in total pressure at Mach numbers above about 1.6, and a double-shock intake is therefore designed, with a streamlined central body mounted concentrically

engine-instrument systems, such as a miniaturized tachometer generator which, as it runs filled with oil, can be used in temperatures very much hotter than usual. Another Smiths product is a remote inductor pressure-gauge for liquid pressures up to 200 p.s.i.

Smith-Clayton Forge, Ltd., Lincoln, are important suppliers of turbine discs and compressor wheels, which are drop-forged in heat-resistant steels.

Smith's Stamping Works (Coventry), Ltd., Ribble Road Works, Humber Avenue, Coventry, turn out large quantities of steel drop-forgings, with the emphasis on high-temperature gas-turbine alloys.

Solar Aircraft Co., San Diego, California, have long specialized in high-temperature problems. Their Solaramic process for the ceramic coating of metal surfaces is now in world-wide use, and is employed in the manufacture of numerous piston engine exhaust assemblies and is becoming standard in the hottest parts of turbojets—for example, the GE J47 is now able to use poorer-quality alloys owing to the Solaramic coating on the flame tubes and combustion chambers.

Sparcatron, Tuffley Crescent, Gloucester, specialize in spark-machining processes, which are showing remarkable savings in the production of all manner of dies and other tool-room fields.

Super Oil Seals and Gaskets, Ltd., Factory Centre, Birmingham 30, manufacturers of oil seals, rubber mouldings and similar products, also hold British Empire manufacturing and sales rights for American Aeroquip flexible hosing.

Taylor, Taylor and Hobson, Ltd., Leicester, are known for their great variety of optical inspection and measuring equipment. Particularly appropriate is a new turbine blade-edge microscope, which enables a 40-times-magnified view of the edge of the blade to be compared accurately with a master profile. By this means, errors of one-thousandth of an inch are rendered visibly obvious.

Tecalemit, Ltd., Plymouth and Brentford, call themselves "the authority on lubrication," and it is certainly true that almost all our present production aircraft have this company's micro-pumps, oil and fuel filters and elements.

Teddington Controls, Ltd., Cefn Coed, Merthyr Tydfil, South Wales, mass-produce an immense amount of equipment directly related to aero engines. Typical examples are the oil cooler anti-surge valve for Merlin power plants, the thermostatic oil cooler valve for Heron Gipsy Queen 30 Mk 2s, an engine starter time switch for the Viscount Dart, a starter cartridge selector switch for various aircraft using the Avon, Sapphire and Ghost, a flamestat for the Britannia Proteus jet-pipe, and a wide range of hot-air-handling equipment. In the last-named field, it may be noted that all of the thousands of Avons built have Teddington hot-air valves, a typical standard pattern being Type FKH/A/9 for the Swift, with temperature limits of −55 to 320 deg F, air pressure of 150 lb/sq in, 1¼in bore, reversible electric actuator with built-in brake, and total weight of 5 lb. On the Canberra a 2in double valve is fitted, while the Vulcan has a big four-way valve, all outlets being of 4in bore. A particularly impressive performance is put up by the FKH/A/21 Proteus anti-icing valve, which accepts engine gas at no less a temperature than 700 deg C. This gas is mixed with intake air by means of a jet pump, and the valve follows Teddington practice in being made of H.R. Crown Max, with a precision-fitted carbon sliding gate valve. Owing to the high temperature at which these valves work, remote actuation is used.

Teleflex Products, Ltd., Chadwell Heath, Essex, make the well-known series of controls of this name, which go into every R.A.F. "super-priority" aircraft.

Thermal Control Co., Ltd., Marine Works, Sackville Road, Hove, Sussex, market the Speed Development Company's patented thermo-electric continuous re-setting fire detector, and a range of special pressure switches.

H. I. Thompson Co., 1731 Cordova Street, Los Angeles 7, California, make "Refrasil" lightweight, removable, tailored heat-insulating blankets for various airborne applications—such as insulation of the air-bleed manifolds on the Allison J35. Refrasil is made in various forms, but all are based on a heat-resistant fibre capable of maintaining a temperature-difference of 900 deg F across a half-inch sheet.

Thompson Products, Inc., Cleveland 17, Ohio, have so many different products that only a few can be listed. They are probably the world's biggest manufacturers of compressor and turbine blading, and possibly of piston-engine valves as well. Fuel booster pumps are typical of another field, the double-ended series being capable of picking up fuel from either end under heavy negative-g loads at flows exceeding 3,000 gal/hr. Other fuel pumps are driven by the engine, electrically, or by an air turbine. The fuel pump they manufacture for the American J65 Sapphire turbojet is the Dowty ENG.129, made under licence from the English firm. Thompson Products also have a new Tapco plant, where various cermets (ceramic-and-metal) are being developed. One of these, a titanium carbide/metal mix, is hoped to allow gas temperatures in turbojets to rise by as much as 200 to 300 deg F. Applied to matched turbine discs and blades, the new cermet has a ductility approaching that of the best metal alloys, and is better above 1,000 deg F. As hard as glass, it can be bent 90 deg over small radius, and resists impacts from foreign bodies in the engine. A year ago, this Tapco plant was delivering 250,000 compressor blades a month using a sintered method with copper as the bond metal.

Tungum Sales, Ltd., Brandon House, Painswick Road, Cheltenham, Glos, supply Tungum alloys in all standard forms, as well as being tube manipulators and small - part machinists.

Ultra Electric, Ltd., Western Avenue, Acton, London, W.3, are one of the principal British suppliers of electric or electronic control systems for turbojets and turboprops. Various systems have been specially designed for such companies as Armstrong Siddeley, de Havilland and Bristol. Most of these units continuously co-relate r.p.m., jet-pipe temperature, fuel flow and other parameters to the position of the pilot's single-lever engine control.

United States Navy. At the Naval Experiment Station in Philadelphia a considerable amount of research has been undertaken towards the development of thixotropic (literally "changed by touch") compounds for use as lubricants or inhibitors in stored engines. A typical preparation is a half-and-half mixture of a lubricating oil and an unstated formula which turns to a hard gel and sets inside the engine. Thus, it does not drain off, neither is it affected by extended storage even in high ambient temperatures. For depreservation, the engine is turned over slowly by hand and the mere act of moving, shaking or stirring the gel causes the latter to break down and revert to a liquid condition.

United Steel Companies, Ltd., 17 Westbourne Road, Sheffield 10, have a new gas-turbine steel combining a tensile strength of 40 tons/sq in with favourable welding characteristics. Named "Fortiweld," it is proving highly suitable for a variety of engine welded-sheet assemblies working at 450 to 500 deg C, at which temperature it can withstand service stresses two or three times those permissible for mild steel.

Vanderveil Products, Ltd., Western Avenue, Park Royal, London, W.3, are world-renowned for thin-wall

within the intake, forming the first (oblique) shock at its tip. This streamlined body is an obvious place in which to put the fuel pump, controls and other paraphernalia, particularly as its drag is subsonic at all flight Mach numbers, unlike any other part of the engine, or the aircraft to which it is attached. The fuel pump is therefore inserted in the fattest part of the streamlined inner body, driven by a turbine working on ram air. The pump will be approximately 1/300 the weight of an industrial pump of the same capacity; as for the control system, this merely has to be capable of starting or stopping a 400,000 h.p. machine in approximately one second (industrial plant of this capacity, if it existed, would need half a day to bring up to speed).

It can be seen, therefore, that the development problems of really useful ramjets are very great. Just to make matters worse, flexibility in operation can be obtained only if the length of the intake cone and the area of the propelling nozzle are both made adjustable. The whole unit has to be made of materials suitable for the temperatures involved and—remembering that the stagnation air temperature has been quoted above as 1,100 deg F—it appears doubtful if any cooling can be provided for longer than a few seconds' duration. Again, as the power/weight ratio of the engine is about 300 h.p./lb, the whole unit is subject to extremely violent vibration and acceleration loads.

There is only one way to tackle a problem of this magnitude—crudely, to "suck it and see." Once material-testing and the development of the pump, control systems, burners and flameholders has been taken as far as possible on the ground, there is no short-cut around full-scale flight testing. Such a procedure will be expensive, even with a recoverable test-vehicle. But it has been done a thousand times across the Atlantic, and sooner or later we shall follow suit.

ROCKETS. Large-scale production of rocket motors is already a requirement, both for assisted-take-off and also for use as primary or combat propulsion of various types of manned and pilotless aircraft. These motors form a propulsive jet by the dissociation or combustion of one or more liquid fuels; solid-fuel motors can be ignored for such applications as their endurance is too limited. The fuels contain everything which is needed to form the jet and consequently rockets (unlike air-breathing engines) can function independently of the earth's atmosphere; at the same time their fuel consumption is very high compared with that of engines which extract oxygen from the air.

The initial requirement will state the thrust, minimum duration and probably the type of fuel to be used. A wide choice of fuels is available, although it is narrowed down considerably where the motor is intended for a manned aircraft. For the sake of argument it is assumed that an a.t.o. motor is to be developed, running on the dissociation of hydrogen peroxide, with hydrocarbon fuel added from the aircraft tanks.

The original design-work is fairly straightforward, and is split among sections responsible for the mechanical design, fuel and starting system and combustion chamber. The company can, from the thrust requirement, immediately work out the necessary flow of the propellants specified, and can quite rapidly get a good idea of the combustion chamber pressures and temperatures which will be required. The characteristic length of the chamber (the length of a chamber of the same volume as that to be used but with a uniform cross-section area equal to that of the nozzle throat) is determined. Much calculation is then needed to see how slight variations in chamber shape would affect performance.

It is probable that several chambers will be built, all slightly different, and initially tested with water to ensure that they can withstand the combustion pressure. The fuel system is also worked out and this is similarly examined using water as the pumped medium. This technique gives results almost indistinguishable from those which would be obtained with the correct fuel and saves a lot of expense and trouble, for it must be remembered that modern rocket fuel systems have enormous capacity and even a few seconds of rig-testing might require up to several hundred pounds of fuel.

Probably most of the work will be devoted to the control system, which must be precise and foolproof. And if the motor is designed to be responsive to a throttle right down to about ten per cent of full thrust the company will have a real job on their hands.

Eventually a complete motor is set up in the test bed. It will probably look rather a mess, for the components will not only be covered with test leads, but will be more spread out than in the other prototype motors which will follow. It is also likely that many of the parts will be left very rough, with plenty of metal on them, so that as the behaviour of the engine becomes known the excess can be pared off and the whole unit made much lighter and more presentable. At this stage of testing it is also possible that the fuel pump (which may be driven by a permanganate-turbine unit) will not be ready, so that fuel will have to be pumped in by a separate engine—and there are rocket fuel pumps requiring a drive power exceeding 1,500 h.p.

The initial firing will be carried out cold, i.e. the peroxide will merely be pumped through a catalyst and dissociated at a relatively low temperature. These runs should give about half the design-thrust and, if all goes well, the hydrocarbon fuel will gradually be worked in until the motor is giving full thrust at top temperature. But trouble is certain to be met.

Strain-gauging and thermocouples may show that excessive local temperatures are dangerously weakening the strength of the chamber. Various solutions present themselves: either increased cooling can be provided, or the heat-absorbing capacity of the chamber can be increased by thickening the walls, or the chamber can be lined with a ceramic or other refractory. The trouble is that those substances most resistant to extreme temperatures are usually poor from the heat-conductive viewpoint, so that if full

Transferring liquid oxygen from a B.O.C. spherical tanker to the Hawker P.1072 in which the Snarler rocket was tested. The gas is exhausting through the lower vents and rapidly evaporating.

The Quest for Power . . .

power is needed for any length of time the problem of getting the heat away is very great. In any case it is virtually certain that regenerative cooling will be employed, in which one of the fuels is pumped through a jacket surrounding the chamber before being injected.

On really hot rockets, such as those using liquid oxygen and alcohol or kerosine as fuels, combustion studies are of extreme importance; and, owing to the temperatures involved, they pose some difficulty. One solution is the manufacture of facsimile combustion chambers in a transparent material, so that what goes on inside can actually be watched and filmed by a high-speed camera—for a second or so before the chamber breaks down under the heat. This method has been used by many firms, and by the O.N.E.R.A. group in France. Another line of approach is spectrographic flame-analysis, which is now being superseded by an improved method using an interferometer. The latter method, employed by the American General Electric company, uses a sodium-vapour lamp as reference, the interferometer magnifying the radiation spectrum for the flame. It is possible to examine the temperature-distribution over quite large portions of flame, from which it is possible to obtain a fair estimate of how much heat energy is being converted into thrust.

A few hours' running should tell the engineers more about a rocket than a hundred times as much gas-turbine development time. This is because the initial runs are rarely longer than a few seconds duration and a lot happens in a short time. Later, quite long runs will be undertaken, with correspondingly adverse effects on both the company's fuel bills and the local noise level. Indirect vision is usually employed for observing the initial firings, but a new motor soon ceases to be an unknown quantity of doubtful safety—as it must, if a pilot is to fly with it.

The final development is merely a matter of arranging all parts of the motor into a tiny space, usually lying within a cone of about 30 deg included angle forward of the propelling nozzle. It is also, of course, essential to check that each part in the final configuration can do its job without succumbing to the attack of heat, pressure, vibration, corrosion or erosion. Acceptance trials follow and the unit is then cleared for service. Flight testing plays a relatively minor rôle, since the rocket motor should work equally well in any atmosphere: its behaviour under acceleration loads does, however, have to be studied in the air.

Handling rocket fuels is no trouble provided that regulations born of experience are obeyed. Thus, with hydrogen peroxide of the concentration used in rockets, it is essential that the test cell be kept damp with water running down the walls and across the floor. Any spilt peroxide is thus diluted and rendered harmless. There is a risk of fire if peroxide is allowed to come into contact with organic materials, oils or some metal filings, and if such substances find their way into the peroxide tanks dissociation will cause a rapid build-up of pressure. Efficient venting is, therefore, a necessity to release the resulting oxygen and steam: a pressure gauge should also be watched and any pressure build-up counteracted by diluting the contents of the tank with water. Before every test run the rocket itself is thoroughly purged with steam to get rid of any kerosine or other hydrocarbon fuel which may be left in the combustion chamber.

The need for precautions is far more keenly felt with other fuels—such as combined petrol and concentrated nitric acid—in which violent explosions can result from a moment's carelessness. Admittedly, the specific impulse obtainable with peroxide (a little over 200 sec) is barely half what designers can see with other propellants but, if rocket motors are to take their place alongside the more established types of aero engine, they must not demand special procedures. It must, in fact, be possible to have a rocket-powered aircraft on something like two-minute standby with its tanks filled. But this restriction need not apply to guided weapons which can be tanked-up at the last minute and fired remotely from a protected block house. The motors of such weapons are likely to be very fierce indeed.

precision bearings, particularly for main bearings and big-ends of piston engines.

Vokes, Ltd., Henley Park, Guildford, Surrey, are one of the world's best-known companies for filtration. All kinds of filter are in production for piston engines, turbojets, turboprops and test beds, as well as silencing and flame-damping equipment. Vokes fuel-filtering elements are mounted integrally in the structure of the Olympus.

C. C. Wakefield and Co., Ltd., 46 Grosvenor Street, London, W.1, are supplementing their "Castrol" lubricating oils by a new synthetic turbine oil, to spec. R.D.E./465; they are also expanding their range of lubrication equipment.

James Walker and Co., Ltd., Lion Works, Woking, Surrey, are by no means relying solely on their "Lion packing" reputation; their new products include "Univoil," a synthetic rubber which resists mineral and synthetic oils; "Twilstele" woven steel and asbestos for 800 deg C gasketing; "Fluolion" P.T.F.E. mouldings and tapes; and a wide variety of O-rings and mouldings in all kinds of synthetic and silicone rubbers and fabrics.

Waymouth Gauges and Instruments, Ltd., Station Road, Godalming, Surrey—who, like K.L.G., are partners in the Smiths group—manufacture Smiths-Liquidometer fuel-system measuring equipment. More closely related to engines is the Waymouth gas-turbine temperature-control amplifier, which automatically reduces the fuel flow once a predetermined temperature has been reached in the gas flow immediately behind the turbine. The control is effected by an electro-magnetic valve coupled to a hydraulic servo unit.

Wellworthy, Ltd., Lymington, Hants, long-famed for piston-rings, now also make gas-turbine sealing rings, as well as Al-fin bimetallic bonded cylinders (aluminium on steel or iron), jointing compounds, and light-alloy die castings.

Westool, Ltd., St. Helen's Auckland, County Durham, make bonded, sealed, and temperature-resistant solenoids for turbojet control circuits.

S. S. White Co. of Great Britain, Ltd., Britannia Works, St. Pancras Way, London, N.W.1, are the British branch of an American company whose flexible shafting is widely used in American engines; in at least one engine an S. S. White flexible drive comes out of the front of the engine and drives an accessory mounted on the side of the intake.

Henry Wiggin and Co., Ltd., Wiggin Street, Birmingham 16, in conjunction with the Mond Nickel company, make that most famous of all gas-turbine alloys—Nimonic. One or other of the Nimonics is used for the turbine-blade material of every British gas-turbine aero engine, and the alloys are also widely used overseas. After starting the British industry off on a firm basis with Nimonic 80, Wiggin have gone on to produce 80A, 90 and now 95, which has alone permitted the increase in gas temperature found in the latest Avons and similar engines. Nimonic 90, with a trace of cobalt, is coming into wide service at 800-870 deg C, and 95 is a significant advance even over 90, although full details cannot yet be published. The former standard material for flame tubes, Nimonic 75, has given way to Nimonic F, with a higher iron content; Nimoply is also likely to be of great consequence, in which two layers of 75 form a sandwich with a copper filling. The company are also doing a lot of work in the development of spheroidal-graphite cast irons, which are gradually being appreciated as excellent gas-turbine structural materials.

Yorkshire Engineering Supplies, Ltd., Leeds 12, have "Eatonia" water-cooled phosphor-bronze bearings and bushes on the Rolls-Royce Avon.

Aero Engines 1954

The World's Leading Aero-engine Constructors and their Products Reviewed

A GREAT many people, both amateur and professional —the latter, it may be said, include aircraft designers, pilots and other members of the industry—have a reasonably comprehensive understanding of how and why an engine works, yet have become slightly disconcerted by the rapidity and diversity of modern aircraft powerplant development. The narrative which, on pages 429-444, precedes this review, may help them better to understand what lies ahead in the aero-engine field—and also, perhaps, why some of it lies so far ahead.

The pages which follow are, broadly speaking, a survey of all the more important established engine manufacturers, giving an account of their work and prospects and dealing with each of their present engine designs in turn. In addition, every non-secret engine of serious importance is the subject of a concise table of data, and some 80 are also illustrated by side-view line drawings, all of which have been prepared by our artists during the past few weeks.

Though the statement may seem a truism, engines really are very important—more so, in certain aspects, than the aircraft they drive. A good modern aero engine is an immense national asset; it is the result not only of a multi-million-pound development but the focal point of aircraft development programmes costing many millions more. Everything that is done by the aircraft of the future—stratospheric reconnaissance, short-haul transport, supersonic combat or jungle warfare with helicopters—will be vitally dependent upon the provision of engines of the right sort at the right time. All kinds of engines are needed: for fighters, the requirements are thrust, high-altitude performance, low frontal area, reliability, economy and durability, approximately in that order of importance; but an engine for an airliner (which, as this country has shown, may well be the same basic design) has safety, reliability, economy and longevity as prime requirements, with performance, size and weight relegated to the background.

Such fundamental differences are not externally obvious except to the really trained eye. But the basic shapes and characteristics of present aero engines are well brought out by the following 23 pages and our only regret is the absence of any really up-to-date Russian power unit. We feel sure, however, that readers would prefer us to print only what we know to be accurate rather than a string of rumours—which are legion—about Soviet developments.

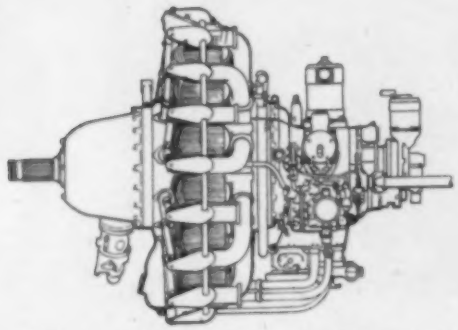
Of engines from the rest of the world, all figure in the pages which follow. Following Britain comes the United States, if only on the score of sheer production. Already the Allison company has delivered its 25,000th turbojet, and General Electric are not far behind. But America is not all production and no development; if she were, her massive factories would be in a sorry state in five years' time. Enormous facilities exist there for detail engineering development and for fundamental research, which would allow her to draw ahead in the years to come—were it not for the knack which we in Britain have of developing really good engines. That is not to suggest that the British companies can continue to produce world-beating engines without the type of backing available to their counterparts in America; it is imperative that we keep fully up to date in such fields as the development of special materials for high- or low-temperatures, the use of electronic calculating machinery, the automatic machining of complex parts, and the use of really high-capacity test plant capable of providing compressed air or hot gas at the right temperature, pressure and, above all, sheer volume.

With such tools, there is no reason to doubt that our position as the world's top-ranking designer of aero engines will be maintained. Already our gas turbines are in production, under licence, in Sweden, Switzerland, Italy, France, Belgium, Argentina, and the U.S.A.—and, without a licence, in Russia. This state of affairs reflects immense credit on our engine companies, and also on the Ministry of Supply, under whose *aegis* is done almost all present aero engine development. The Gas Turbine Collaboration Committee, the fuel and oil companies, the accessory manufacturers and, by no means least, the firms responsible for special materials, can all share in mutual congratulation for a huge job well done.

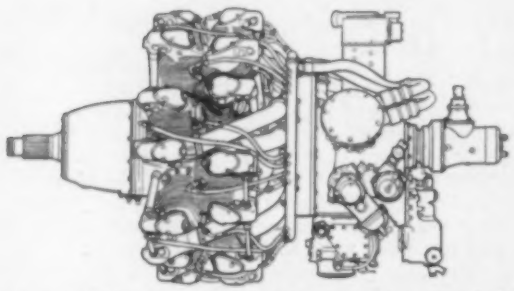
Production, too, is going very well, and more than one aircraft factory is probably finding storage of delivered engines almost an embarrassment. (The same sort of situation has, we hear, arisen across the Atlantic.) In fact, our superpriority engines—the Avon, Sapphire, Olympus, Double Mamba, Proteus and Dart—are without exception progressing well and showing every indication of forming the backbone of our civil and military power for years to come. But there is certainly not going to be much time for taking stock, because the future is going to be an even greater challenge than was the immediate past. All kinds of possibilities are opening up, culminating in the conquest of space itself.

Aero Engines 1954 . . .

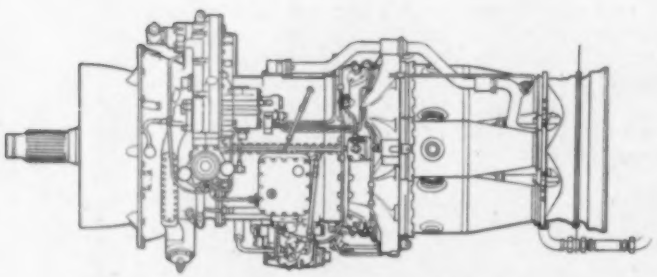
GREAT BRITAIN



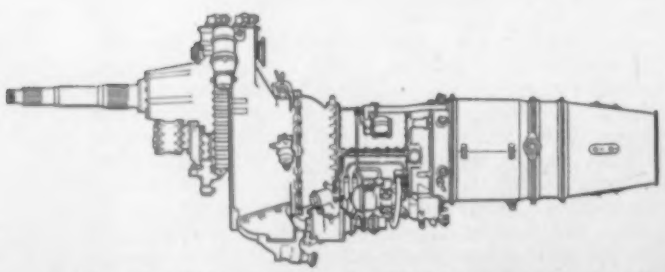
Alvis Leonides 502/5 (fixed-wing) nine-cylinder, air-cooled poppet-valve radial. Cylinder bore and stroke, 4.8 by 4.41in; swept volume 718.6 cu in (11.78 litres); overall diameter, 41.5in; length, 54.4in; dry weight, 796 lb; maximum power, 570 b.h.p. at 3,000 r.p.m. at 8 lb boost at 1,750ft.



Alvis Leonides Major 1-1 (fixed-wing) fourteen-cylinder, two-row radial. Cylinder size as Leonides, giving swept volume of 1,117.8 cu in (18.28 litres); overall diameter, 38.9in; length, 70.9in; dry weight, 1,150 lb; maximum power, 870 b.h.p. at 3,000 r.p.m. at 8 lb boost at sea level.



Armstrong Siddeley Mamba ASM.3 single-shaft turboprop. Ten-stage axial compressor, six combustion chambers and two-stage turbine. Mass flow, 18.5 lb/sec with pressure ratio 5.35:1. Overall diameter, 29in; overall length, 87.3in; dry weight, 780 lb; maximum power, 1,320 s.h.p.+405 lb thrust (1,475 e.s.h.p.) at sea level at 15,000 r.p.m. with specific fuel consumption 0.8 lb/hr/e.s.h.p.



Armstrong Siddeley Double Mamba ASMD.3. Power sections identical with Mamba ASM.5. Overall width, 52.8in; height, 48.8in; length, 102.25in; dry weight, 2,170 lb; maximum power, 2,960 e.s.h.p. at sea level.

Alvis. *Alvis, Ltd., Coventry.* It was in 1935 that the Alvis car company decided to enter the aero-engine manufacturing industry. A fine new factory of over half-a-million square feet was built in Coventry, and very fully equipped. The company first turned its attention to the development of a number of radial engines of basic French Gnôme-Rhône design, but effort was soon focussed on an engine of 450 h.p. of all-Alvis design, which appeared to fill a then-existing (1938) gap. As the Leonides, this engine still fills a gap, although its power has risen considerably.

The company's immense war-time production of Merlins, and work on American power units, held up the new engine but, at the end of the war, Alvis gained a development contract for a largely redesigned Leonides, and this unit has since gone into world-wide service. It has now been joined by the Leonides Major, for the development of which—and for increased production of the Leonides—extensive new test facilities have been built. Alvis is unique among the established British engine manufacturers in not having entered the gas-turbine field.

Leonides. Twelve years' development of a sound basic design have produced this exceptionally fine and compact power unit, which has found wide acceptance for all types of civil and military fixed- and rotary-wing aircraft. Everything about the engine reflects its modernity and complete equipment, a typical example being the Hobson fuel-injection system providing for single-lever control.

All Leonides are equipped for use in all climates, and a constant-speed unit, electric or cartridge starter, and any other accessories can be fitted. For rotary-wing aircraft a special family of engines exists, devoid of a reduction gear but with a cooling fan and clutch and equipped to run with the crankshaft vertical. The engine is in large-scale production, and is likely to remain so for many years.

Leonides Major. It has long been evident that a demand exists for a good British power unit of about 900 h.p., and Alvis have accordingly prepared a 14-cylinder, two-row engine to meet fixed- and rotary-wing requirements in this category. Development is now proceeding against a M.o.S. contract, the work being initially assisted by the engine's close detail resemblance to the Leonides; work actually began in January 1951, and the first Leonides Major ran on July 11th, 1953.

Owing to the reduction in the number of cylinders in each row the crankcase diameter has been reduced, and this has resulted in the excellent overall diameter of 39in; for fixed-wing aircraft (such as the Handley Page H.P.R.3) the engine cowls beautifully, while in the Bristol 173 the slimmer engine will permit intercommunication between the nose compartment and the cabin.

The Leonides Major embodies every modern development and some components are interchangeable with similar Leonides parts. Naturally enough, one family of Majors is being prepared for special helicopter applications, generally without a gearbox and equipped to run with the crankshaft at any angle between horizontal and vertical. Large-scale production is a certainty, and the company are impatient to get the engine into the air. For this work the former Mamba-Marathon 2 will be used as a test bed, and it may be airborne in about two months' time.

Armstrong Siddeley. *Armstrong Siddeley Motors, Ltd., Coventry.* Well-known before the war for medium- and high-power radial engines, Armstrong Siddeley have since concentrated entirely on axial-compressor gas-turbines. As far back as 1939 the company was involved in this field, in the design and manufacture of various research units, and real effort was first applied about 1942, the project being a 2,500 lb thrust turbojet with an s.f.c. less than unity. This engine, the A.S.X., ran nine months later, and formed the basis of the Python turboprop.

The Python passed its acceptance test in 1945, in which year work was started on the design of a 1,000 h.p. engine, which has evolved as the Mamba. In October 1948 Armstrong Siddeley took over responsibility for the Metrovick Sapphire, when the latter company abandoned aero-engine work; and, although an immense amount of work was needed to knock the 1948 Sapphire into shape, it gave Armstrong Siddeley a head-start into the big-turbine field.

The company have now taken all the engines described here—and they are a remarkably diverse lot—to a high pitch of development. With the exception of the experimental Snarler, all are in very-large-scale production. The Snarler itself has been of great value in teaching the company how to develop efficient bi-fuel rockets and it may be confidently assumed that something bigger in this field is on its way.

Mamba. The first engine designed as a turboprop ever to take to the air—in a Balliol in May 1948—the Mamba has since been

considerably developed to give twice its design power of 1,000 h.p. A feature introduced for the first time is a vaporizing fuel burner, unique to Armstrong Siddeley engines, which gives very good combustion with a low supply pressure. Early in its career the mass flow of the Mamba was increased by taking off the three last compressor stages and adding three larger rows at the front; there has also been considerable modification to other parts of the engine.

For some years, the ASM.3 was the standard engine, giving 1,475 e.s.h.p., and fitted with six combustion chambers, a torquemeter, and a reverse-torque switch for auto-feathering. This engine, which is illustrated, forms the basis for the Double Mamba ASMD.1. The ASM.5 is a considerably revised engine with an annular combustion chamber; it does not exist in single form, and serves as a development engine for the ASMD.3.

The most important Mamba is the ASM.6, which is still largely secret. It can, however, be said that it will be the most powerful and efficient of all Mambas and a unit of this class may power the production Seamew. Flight trials will soon begin in the company's Dakota.

Double Mamba. Initially developed for the Gannet, this remarkable engine is formed by attaching the power sections of two Mambas to a common gearbox driving two separate co-axial airscrews. Each power section retains its own fuel, oil and control system, and can be shut down independently of the other to permit extended economical cruising. Each drive includes a free-wheel, and the 100 s.h.p. accessory gearbox drive takes power from whichever engine is running the faster, although both sections can be synchronized. Carrier operations have caused the Double Mamba to be developed as a constant-speed engine, running at 14,500 r.p.m. (except at take-off) with a very powerful airscrew control system, thus making full power almost immediately available for overshooting; the same type of work is responsible for the fact that the engine can run on a variety of fuels, including marine diesel oil.

The Double Mamba ASMD.1 has already been delivered in some quantity; this engine consists broadly of two ASM.3s, the characteristics of which are given above, with a drawing. If desired the engine may be mounted on a pair of tracks along which it can be slid forwards for removal; equipment includes a Rotol accessory gearbox and a separate Rotax or B.T.H. cartridge starter for each power section.

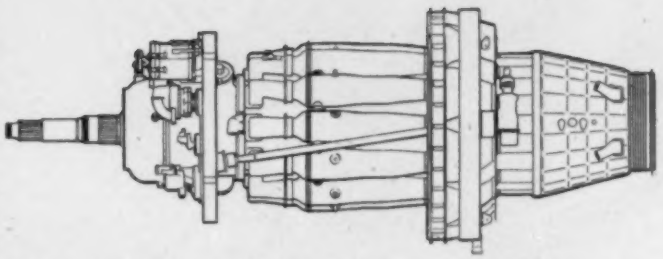
The newer ASMD.3, which is illustrated, consists of two annular-chamber ASM.5s, and is a more powerful and efficient engine than the ASMD.1; this engine is a stepping-stone to the powerful ASMD.4, about which nothing may yet be said. It may be noted that the Double Mamba may satisfy the A.R.B.'s twin-engine safety rules, and the English Electric company are reported to have an interesting civil transport on the drawing boards using this engine.

Python. The Python turboprop had passed acceptance trials in 1945, but a lot of work was needed before it could be used as a fully developed power plant. Many of these troubles stemmed from the difficult application of the engine—the Wyvern carrier-based strike aircraft. The early design of the Python is reflected in almost every part of the engine, and it is much bigger than would be a present-day engine of the same power. It is a reverse-flow engine, with the air flowing forwards through the compressor and back again through the eleven cans which hide the compressor from view.

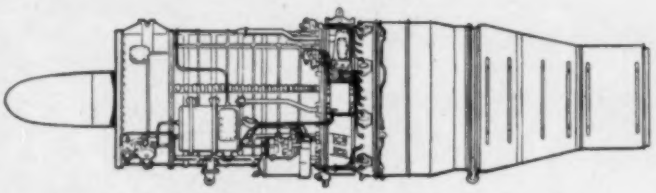
The most common type of Python is the ASP.3, which has a compressed-air starter jet which spins the turbines; an airscrew brake is another fitting, which slows down the engine in about 11 seconds for carrier "striking down." The Python may be replaced by completely new engines, but development is proceeding to produce an exceptionally refined unit capable of long, trouble-free life, a typical example of this work being progressive cooling of the turbine discs. The engine is still in production, the latest models being re-stressed for a turbine starter.

Sapphire. When first taken over by Armstrong Siddeley in 1948—as described above—the Sapphire was the largest turbojet then running anywhere in the world (we believe) and, although in need of much development, it offered great promise. During the first few years, Armstrong Siddeley made and broke various Sapphires, and had them flying in a Lancastrian in 1949. There is today very little Metrovick design left in the engine; the compressor and turbines are noticeably different, the structure has been revised, and the combustion chamber has been completely revised with the Armstrong Siddeley vaporizing burner system; photographs show six fuel pipes each split into six, making a total of 36 burners in all. Sapphires are made by Armstrong Siddeley and at the Gloucestershire factory of Brockworth Engineering.

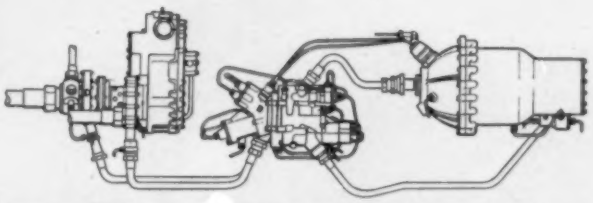
The ASSa.1 flew in the Lancastrian; the Sa.2 flew in a Meteor (rate-of-climb record) and Hastings at about 7,250 lb thrust; the Sa.3 introduced the vaporizing combustion and other features and was air-tested at 8,300 r.p.m. and 7,500 lb; the Sa.6, the latest Sapphire which can be illustrated, has a type-tested rating of 8,300 lb at higher r.p.m., and is in quantity production. The Sapphires 4, 5 and 7 cannot be discussed in detail, but they



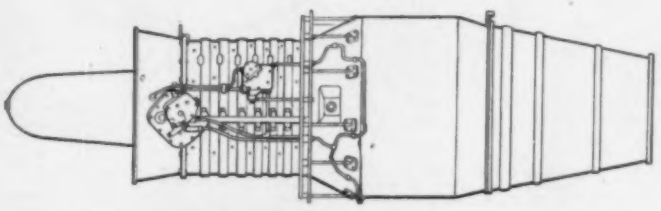
Armstrong Siddeley Python ASP.3 single-shaft, reverse-flow turboprop. Fourteen-stage compressor, eleven combustion chambers and two-stage turbine. Mass flow, 52.5 lb/sec with pressure ratio 5.35:1. Overall diameter, 54in; length, 123.2in; dry weight, 3,450 lb; maximum power, 3,670 s.h.p. + 1,180 lb thrust (4,110 e.s.h.p.) at sea level at 8,000 r.p.m. with s.f.c. of 0.805 lb/hr/e.s.h.p.



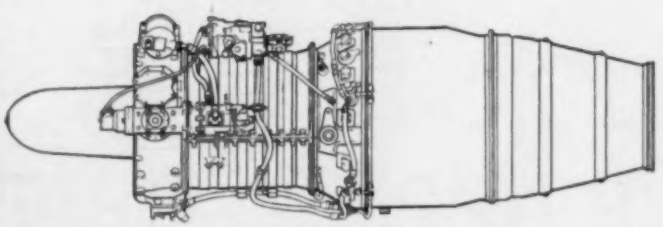
Armstrong Siddeley Sapphire ASSa.6 turbojet. Axial compressor, annular combustion chamber with vaporizing burners and two-stage turbine. Overall diameter, 37.4in; length, 134in; dry weight, 2,600 lb; maximum thrust, 8,300 lb at sea level at 8,600 r.p.m. with s.f.c. of 0.85 lb/hr/lb thrust.



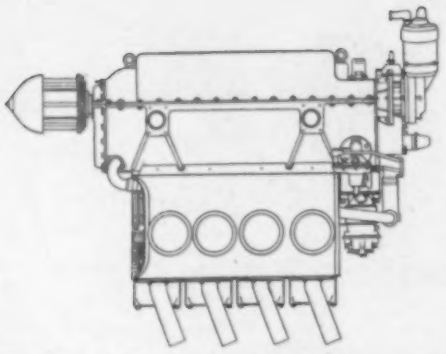
Armstrong Siddeley Snarler ASSn.1 rocket. Dry weight of basic engine, as shown, 215 lb; maximum thrust, 2,000 lb; specific fuel consumption, 20 lb/hr/lb.



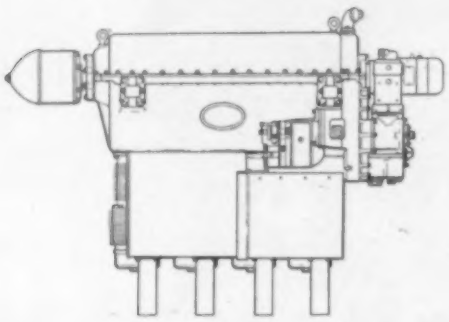
Armstrong Siddeley Viper ASV.3 turbojet. Seven-stage compressor, annular combustion chamber and single-stage turbine. Mass flow, 30 lb/sec with pressure ratio 3.5:1. Overall diameter, 24.7in; length, 65.4in; dry weight, 375 lb; maximum thrust, 1,640 lb at 13,400 r.p.m. with s.f.c. of 1.09 lb/hr/lb.



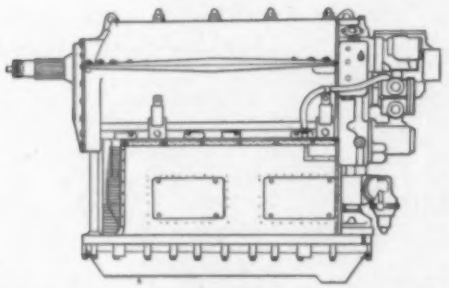
Armstrong Siddeley Viper ASV.5 turbojet. Seven-stage compressor, annular combustion chamber and single-stage turbine. Mass flow, 31 lb/sec. Overall diameter, 28in; length, 65.83in; dry weight, 465 lb; maximum thrust as for ASV.3.



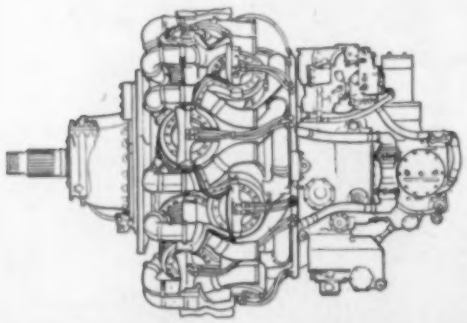
Cirrus Minor 2 direct-drive, unsupercharged, air-cooled, poppet-valve, inverted four-in-line piston engine. Bore, 3.9in; stroke, 5in; swept volume, 243.5 cu in (3.99 litres); width, 18in; height, 25.5in; length, 40in; dry weight, 234 lb; maximum power, 100 b.h.p. at 2,600 r.p.m. at sea level.



Cirrus Major 3, of same layout as Cirrus Minor. Bore, 4.724in; stroke, 5.512in; swept volume, 386.4 cu in (6.3 litres); width, 17.7in; height, 31.3in; length, 43in; dry weight, 333 lb; maximum power, 158 b.h.p. at 2,450 r.p.m. at sea level.



Cirrus Bombardier 702, of same layout as Cirrus Minor, but with direct fuel injection. Bore, 4.8in; stroke, 5.5in; swept volume, 389.12 cu in (6.524 litres); width, 17.2in; height, 31.1in; length, 46.8in; dry weight, 350 lb; maximum power, 180 b.h.p. at 2,600 r.p.m. at sea level.



Bristol Hercules 758, fourteen-cylinder, two-row, sleeve-valve, air-cooled radial, with two-speed blower, copper cylinder heads, and provision for 150 h.p. accessory drive and reverse-pitch airscrew. Bore, 5.75in; stroke, 6.5in; swept volume, 2,360 cu in (38.7 litres); diameter, 52in; length, 70.8in; dry weight, 2,165 lb; maximum power, 2,090 b.h.p. at 2,800 r.p.m. at 13 lb boost at 3,000ft.

Aero Engines 1954 . . .

incorporate later theory and are a most promising family of engines of which a very great deal will be heard. Some will probably have afterburning. More about the Sapphire will be found under the American Wright company.

Snarler. This is a liquid oxygen/hydrocarbon fuel "hot" rocket, giving a thrust fairly constant at 2,000 lb at all altitudes. Fed by a turbo-pump running on the rocket's own fuel it has a duration limited only by tank capacity. The drawing shows the pump on the left, the control unit in the centre (with starting, safety and shut-down valves) and the regeneratively cooled combustion chamber on the right. On p. 444 appears a photograph of the Snarler test-bed aircraft having its rocket fuels put aboard.

Viper. Originally intended solely for the Australian Jindivik pilotless aircraft, the Viper is one of the simplest and cheapest turbojets in the world, notwithstanding its remarkable thrust. As can be seen, the combustion chamber resembles a miniaturized Sapphire unit, with 12 vapourizing burners fed, in short-life Vipers, from a gear-type fuel pump. Features include a very neat disc-type built-up compressor, fully floating turbine nozzle guide vanes and an air-jet starter which spins the turbine.

The Viper 3 has been delivered in large numbers to Australia and is still in production at a 1,640 lb rating; its design life of 10 hr has been far exceeded. The ASV.6 is a 1,900 lb thrust engine, and the ASV.5, also illustrated, is a completely different engine for long, trouble-free service. Principal differences include Nimonic 90 turbine blades (although gas temperatures are no higher), general strengthening of the engine, a more normal "Sapphire-like" fuel system, and with steel blading in the first three compressor stages. This engine is in production for the Percival P.84, and is also mentioned under the French firm of Dassault.

Blackburn Cirrus. *Cirrus Engine Division of Blackburn and General Aircraft, Ltd., Brough, East Yorks.* It was during 1925 that Maj. Halford, now chairman of the D.H. Engine company, cut an Airdisco R.A.F.4a in half and, so to speak, made the first Cirrus engine. This four-in-line unit was the first of a huge family, the development of which has been unbroken right up to the Bombardier. In 1951 the company, which had then long been part of the Blackburn and General Aircraft company, acquired manufacturing and sales rights for the remarkable range of Turboméca engines, details of which are found under the French company. At the moment no Turboméca engines have been made from scratch, but much development work has been completed, including some redesign of the engines, about which more will be heard.

Cirrus Minor. This engine has served well even when overstressed for racing purposes. It can use a variety of fuels, and a cheap de-rated version has been studied for light aircraft competitions. It is normally equipped with starter and generator and can take a v.p. airscrew. The Minor 2A is similar to the 2 (illustrated) except for a stiffened top cover; with a weight of 247 lb the 2A has an overspeed r.p.m. of 2,730.

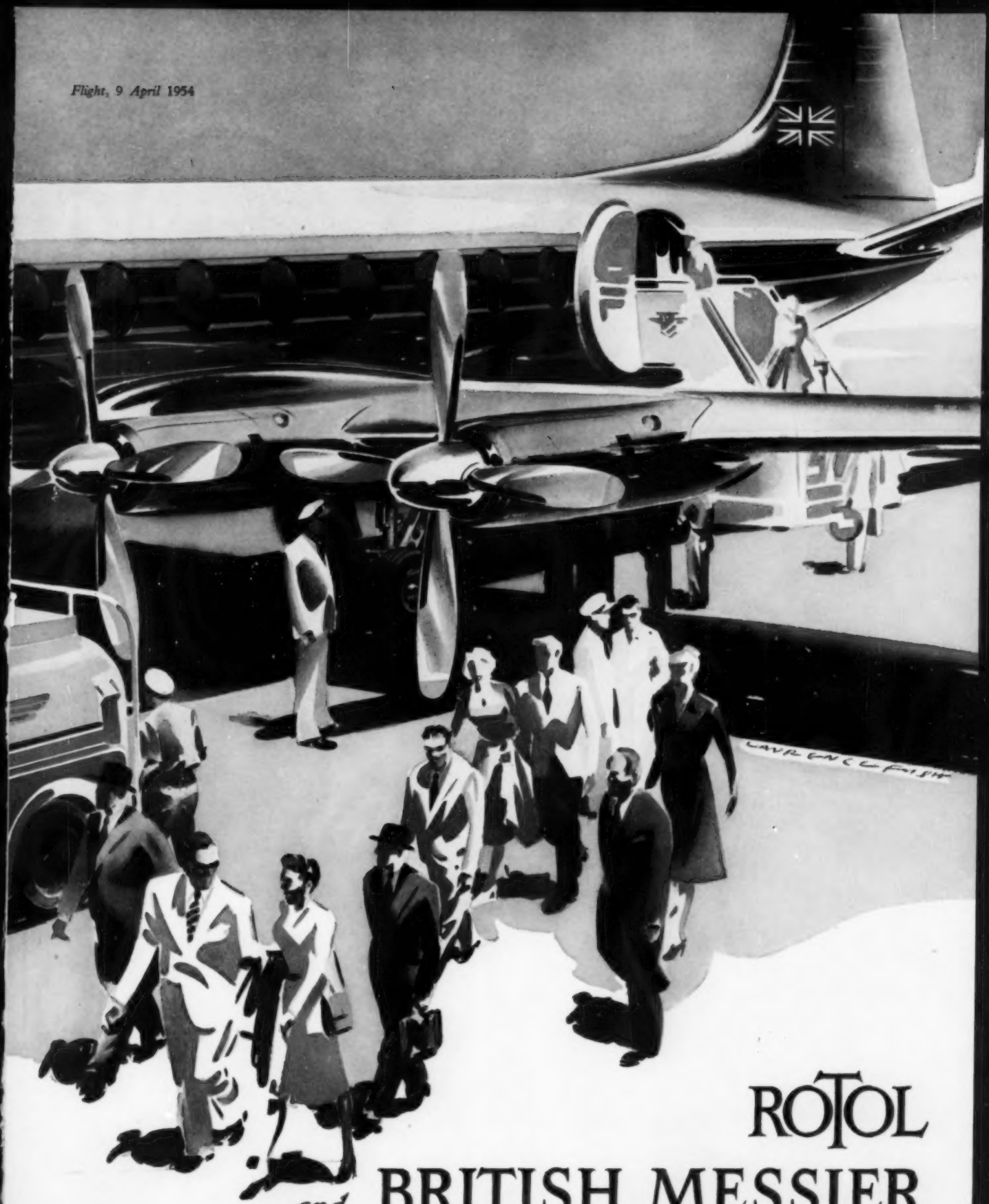
Cirrus Major. No changes have recently been made in this familiar engine, which has a recommended overhaul life of 600 hr.

Bombardier, one of the most advanced designs in its class, the post-war Bombardier has direct fuel injection and an underhead camshaft. A constant-speed airscrew can be fitted, and equipment includes fully screened ignition and, if required, a cartridge starter. It is in production for fixed- and rotary-wing aircraft.

Bristol. *The Engine Division of the Bristol Aeroplane Co., Ltd., Filton, Bristol.* Entering the aero-engine field in 1920 with the famous Jupiter, the company concentrated almost entirely on air-cooled radials; and since before World War 2 design effort has been centred on engines employing a development of the Burt-McCollum mono-sleeve valve. Gas-turbine work began during the war, the first unit—the Theseus turboprop—being run in July 1945. Bristol gas-turbines have all been advanced units of high efficiency, and the engines listed below are all in a class of their own. The company is also devoting much attention to ramjets for guided weapons, and a number of these engines have been flown. The engine division has over 12,000 employees.

Hercules. Some 70,000 "Hercs" have been built, and many thousands are still in world-wide use. Present production centres on the 730 and 750 series, with single-speed blowers. The usual overhaul time is 1,250 hr, and the engine is capable of longer life than this. It is also mentioned under SNECMA (France).

Centaurus. The most important application here is the Beverley, for which the Series 173 is in production. Very like the Ambassador's Centaurus 661, the 173 has a single-speed blower and gives 2,850 b.h.p. for take off. Water injection is fitted and, compared with the 661 illustrated, a new front cover carries the controller for the D.H. steel-bladed airscrew. The 173 is supplied as a complete engine-change unit, with a free-



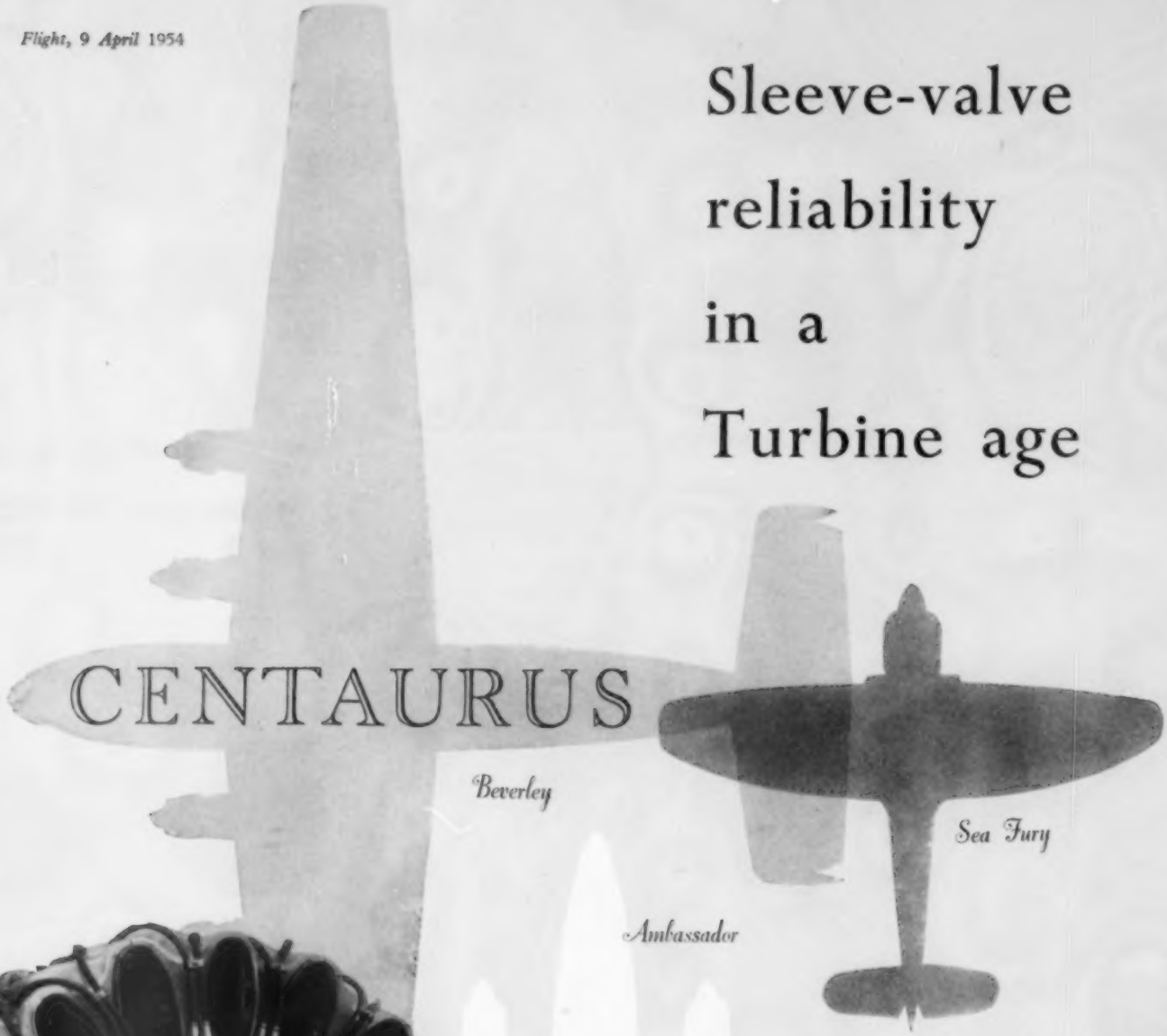
ROTOL

and BRITISH MESSIER

propellers, gearboxes, synchronising equipment, landing gear and hydraulics have

WORLD WIDE ACCEPTANCE

Sleeve-valve reliability in a Turbine age



In Sea Furies over Korea, in Ambassadors flying B.E.A. routes to the Continent, and now in the R.A.F.'s huge new Beverley transport, "Bristol" Centaurus sleeve-valve engines have given and are giving constant proof of their reliability, efficiency and economy. Such qualities will ensure the Centaurus many years of useful application and service.

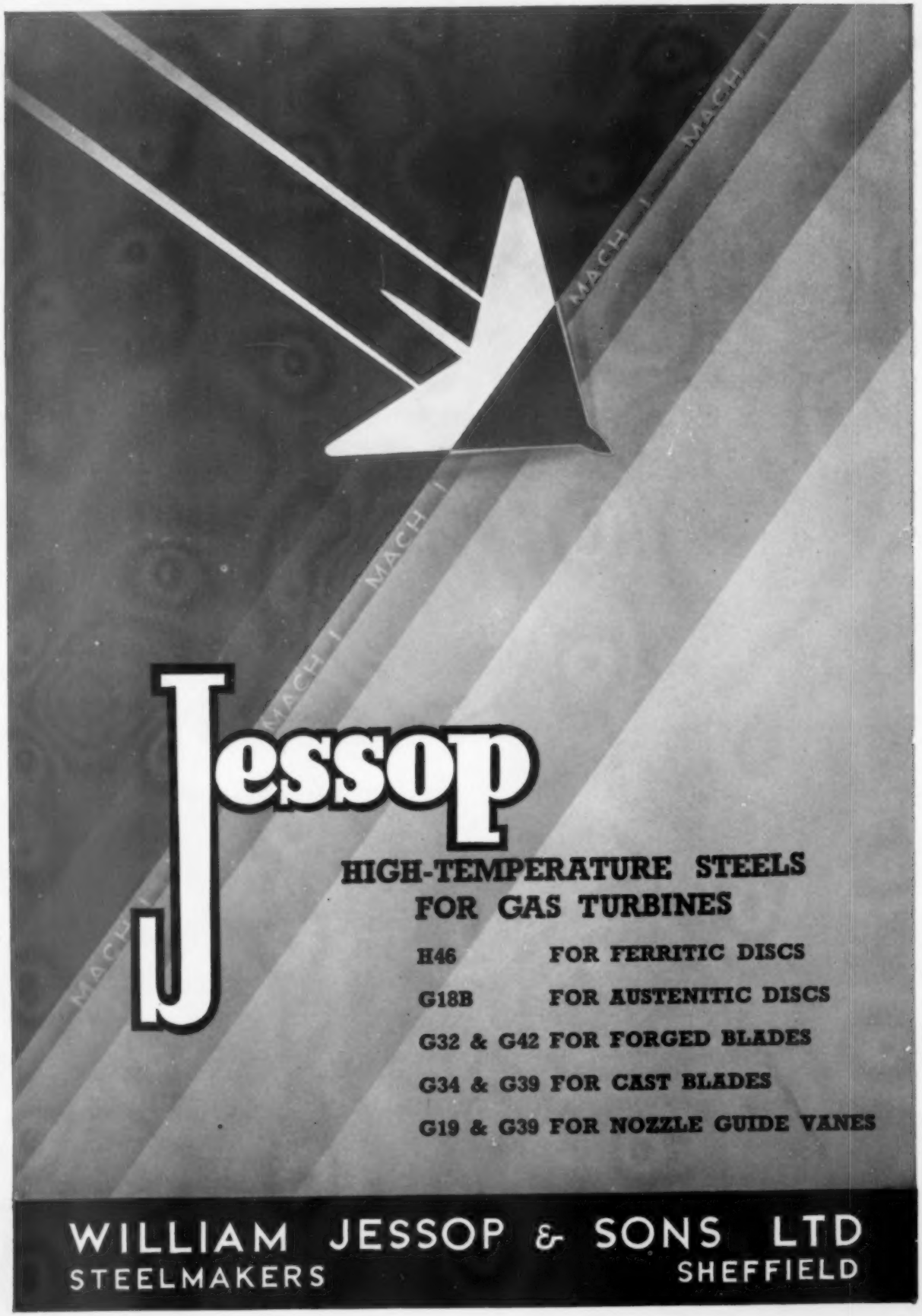
THE *Bristol* AEROPLANE COMPANY LIMITED · ENGLAND

2801

The 10,000,000th blade produced in HIDUMINIUM

by the pioneers of precision forged blades.

HIGH
DUTY
ALLOYS
SLOUGH


MACH 1
MACH 1
MACH 1
MACH 1
Jessop
HIGH-TEMPERATURE STEELS
FOR GAS TURBINES
H46 FOR FERRITIC DISCS
G18B FOR AUSTENITIC DISCS
G32 & G42 FOR FORGED BLADES
G34 & G39 FOR CAST BLADES
G19 & G39 FOR NOZZLE GUIDE VANES
WILLIAM JESSOP & SONS LTD
STEELMAKERS
SHEFFIELD

Aero Engines 1954 . . .

exit cowl and fan cooling for low airspeeds. In B.E.A. service the 661 has averaged 14,000 hr per feathering, a good figure for a new installation, and the A.R.B. has just approved a 1,000 hr overhaul period. Military and naval Centaurus continue to give good service.

Proteus. The original Proteus prototype ran in February 1947, and retained the Theseus reverse-flow, free-turbine layout, the latter feature making for great flexibility and ease of control. From the basic Proteus was developed the Coupled Proteus, used in the Princess flying boat, which is illustrated here to give an idea of the performance and layout of the first form of the engine. The Coupled Proteus power sections were geared to a single shaft from which a contra gearbox supplied power to a contra-rotating airscrew; this is in contrast to the layout of the Double Mamba.

In 1950 the Proteus was completely redesigned, and made more compact, lighter and more efficient and powerful. The centrifugal compressor was brought up against the axial, the mass flow and pressure ratio were increased, and the power turbine was given two stages; in addition, fully shrouded blading was incorporated on the first three turbine stages. The first 15 Britannias (Series 100) have the Proteus 705, of this revised type. But the performance of this engine has proved so encouraging that a further development is in hand to permit operation at still higher power. The new engine, the Proteus 755, will run at 12,000 compressor r.p.m. and, with increased gas temperatures, will provide 3,650 s.h.p. + 1,320 lb thrust, or 4,150 e.s.h.p. Proteus 705s are already running at this rating on development tests.

All Proteus are fully protected against ice, and are also equipped to supply bleed air from the compressor for cabin pressure and de-icing. An Ultra electric control system is fitted to permit extended cruising at precisely controlled compressor speed, independent of airspeed and altitude; this unit also controls acceleration and prevents excessive jet-pipe temperature. Auto-synchronization is standard on the Britannia. A safety device has also been developed to prevent overspeeding of the power turbine when torquemeter pressure falls below a given limit. Altogether, the Proteus is a very valuable engine; present flying is on a 200 hr basis, but this will rise rapidly as experience is gained.

New Turboprop. For what it is worth, we record an American report to the effect that a new Bristol turboprop is on the way. A two-spool engine roughly half the size of the Olympus, it is stated to be throttled to 4,000 h.p. at sea level so that this take-off power can be utilized under any condition of altitude or temperature; not until 15,000ft is reached does the power begin to fall, and the full-throttle curve then gives a power of 2,900 h.p. at 36,000ft. The report links the engine with a "Super Britannia." Bristol's engine division are not prepared to comment on this report.

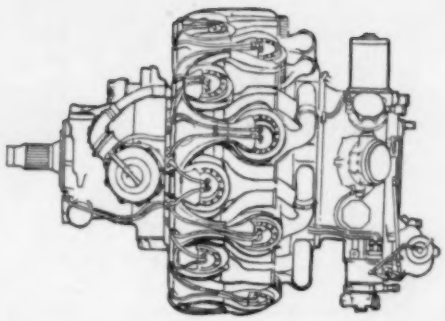
Olympus. First of the production Bristol turbojets, the Olympus was the first two-spool engine in the world, antedating the Pratt and Whitney J57 by some two years. It is probably unmatched in its stability, response to control changes, general behaviour and re-lighting at extreme altitude (the Olympus has been regularly tested at over 60,000ft) and, for an engine of its size and weight, performance and economy. According to American reports, the compressor power has been split between only two turbines, resulting in the low- and high-pressure compressors having six and eight stages, respectively.

The extremely compact combustion chamber is reported to be a stainless-steel drum housing 10 cans and supplied with fuel from 10 duplex burners. The starter drives the high-pressure assembly. The thrust rating quoted was established nearly two years ago, and the company have hardly been standing still in the meanwhile. The Olympus is in super-priority production for the Vulcan, and is also mentioned under the American Curtiss Wright company.

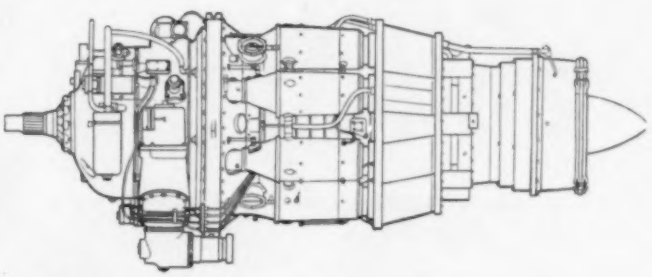
Orpheus. Late last year work began on a new turbojet, designed to provide an extremely modern, efficient and compact source of about 5,000 lb thrust. Its development is proceeding unusually rapidly and there is every indication that it will be widely used in a variety of fighters, trainers and, possibly, missiles. The first announced application is the Folland Gnat. It should be stressed that this engine is in no sense a development of the Saturn.

Saturn. A small axial turbojet of some 3,800 lb. thrust. Some Saturns were built and run over the past few years, but the engine has been abandoned and is not representative of current Bristol practice.

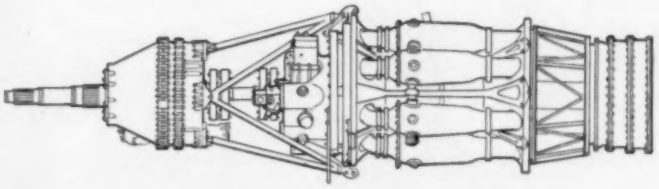
de Havilland. *The de Havilland Engine Co., Ltd., Leavesden Airfield, near Watford, Herts.* Ever since 1927, when the first Gipsy engine appeared, de Havilland piston engines have been steadily developed, to a common basic pattern and, in fact, by a team led by the same men who designed the first Gipsy.



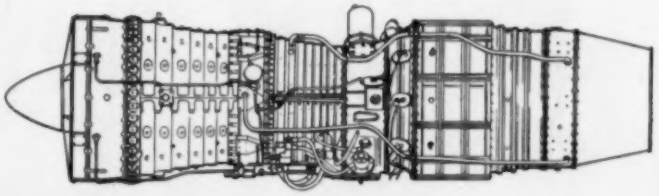
Bristol Centaurus 661 18-cylinder, two-row, sleeve-valve, air-cooled radial geared and fitted with two-speed supercharger. Bore, 5.75in; stroke, 7in; swept volume, 3,270 cu in (53.6 litres); diameter, 56.4in; length, 74in; dry weight, 3,400 lb; maximum power, 2,705 b.h.p. at 2,800 r.p.m. at 13.8 lb boost at 4,000ft.



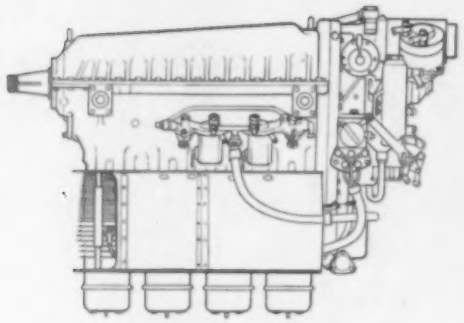
Bristol Proteus 705 free-turbine reverse-flow turboprop. Compressor has 12 axial and one centrifugal stage, driven by two-stage turbine. Airscrew gearbox (0.09 : 1) driven by separate two-stage turbine. Eight, reverse-flow combustion chambers. Diameter, 39.5in; length, 113in; dry weight, 2,850 lb; mass flow, 44 lb/sec; pressure ratio, 7.2: 1; maximum power, 3,320 s.h.p. plus 1,200 lb thrust, giving 3,780 e.s.h.p., at 11,700 compressor r.p.m.; cruising s.f.c. at 35,000ft, 0.495 lb/hr/e.s.h.p.



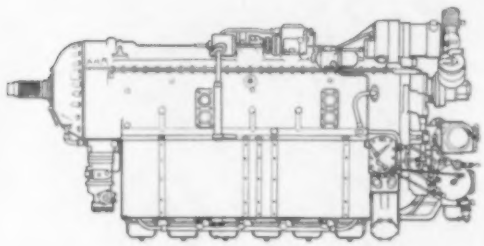
Bristol Coupled Proteus 610, consisting of two Proteus 600-series power sections geared to a common contra-gearbox. Width, 83.2in; height, 41.4in; length, 179.8in; dry weight, 7,730 lb; maximum power, derated to 5,000 s.h.p. plus 1,660 lb thrust, giving 5,640 e.s.h.p. at 10,000 compressor r.p.m. Note: This engine is included principally for historical interest, and is of early conception.



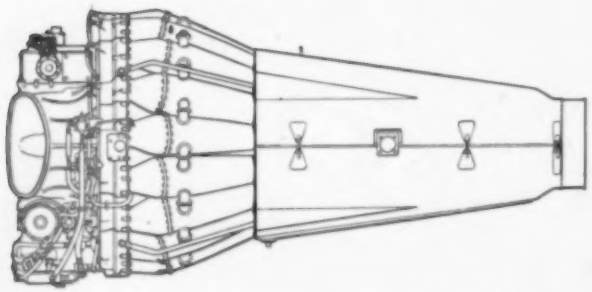
Bristol Olympus BO1.1 two-spool turbojet. The compressor consists of two independent axial units driven by separate turbines. An annular combustion chamber is fitted. Diameter, 40in; length, 124in; dry weight, 3,520 lb; maximum power for publication, 9,750 lb thrust, with s.f.c. of 0.766 lb/hr/lb.



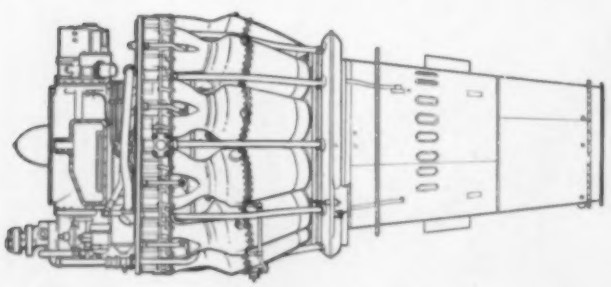
de Havilland Gipsy Major 10 air-cooled, poppet-valve, inverted four-in-line piston engine, ungeared and unsupercharged. Bore, 4.65in; stroke, 5.51in; swept volume, 374 cu in (6.1 litres); width, 20in; height, 30.5in; length, 45.4in; dry weight, 325 lb; maximum power, 145 b.h.p. at 2,550 r.p.m.



de Havilland Gipsy Queen 70 Mk 2 air-cooled, poppet-valve, inverted six-in-line piston engine, geared and supercharged, with injection carburettor. Bore, 4.72in; stroke, 5.9in; swept volume, 622 cu in (10.2 litres); width, 18.7in; height, 33in; length, 70.8in; dry weight, 690 lb; maximum power, 380 b.h.p. at 3,000 r.p.m. at 7.5 lb boost at sea level.



de Havilland Goblin 35 turbojet. Single-stage, single-sided centrifugal compressor, 16 combustion chambers, single-stage turbine. Diameter, 49.85in; length, 100.5in; dry weight, 1,629 lb; mass flow, 63 lb/sec; pressure ratio, 3.67 : 1; maximum thrust, 3,500 lb at 10,750 r.p.m. at sea level; s.f.c., 1.14 lb/hr/lb.



de Havilland Ghost 50 Mk 2 turbojet. Single-stage, single-sided centrifugal compressor, 10 combustion chambers, single stage turbine. Diameter, 53in; length, 121in; dry weight, 2,218 lb; mass flow, 87 lb/sec; pressure ratio, 4.6 : 1; maximum thrust, 5,125 lb at 10,250 r.p.m. at sea level; s.f.c., 1.02 lb/hr/lb.

Aero Engines 1954 . . .

These engines have become a byword for reliability and it may be assumed that, so long as there are any piston aero-engines, there will be Gipsies at work.

In 1941 Major Halford, the company's chairman, began work on the H.1, or Goblin, turbojet, tailoring it to the projected Vampire fighter. Since that date, thousands of Goblins have been made, together with the H.2 (Ghost) which first ran in September 1945. The H.3, a delightful little 500 h.p. turboprop, was not proceeded with. The company's latest turbojet, the mighty Gyron, is just at the beginning of its career. The company is actively engaged in the development of various types of rocket motor, some of which have been announced as a.t.o. units.

Gipsy Major. Following vast wartime production of Majors in several parts of the world, a post-war Major 10 appeared in 1945, based on a slightly larger cylinder size. One of the last British engines to retain a venturi-type carburettor, the Major 10 Mk 2 powers the 1,000-odd British-built Chipmunks. Development proceeds, and a new Major is not far away.

Gipsy Queen. Thousands of wartime Gipsy Sixes and Queen IIs are still in use, but the most important six-cylinder Gipsies are the Queen 70 Mk 2 and 30 Mk 2. The former, illustrated, powers the Dove; it is the most powerful of all present D.H. piston engines and runs at higher boost and r.p.m. than the earlier 70/4. A recent modification is the fitting of hollow-head exhaust valves. The Queen 30 is ungeared and unsupercharged, and has a venturi carburettor. Unlike the 70, it is not made up into the form of an engine-change unit or self-contained power plant. It powers the Heron.

Goblin. Although of 1941 conception the Goblin has remained unchanged in basic form for 13 years and is likely to remain in large-scale production for some time to come—an extraordinary testimony to Maj. Halford's unerring basic precepts. In January 1945 a Goblin gained Approval Certificate No. 1 under the the then-new M.o.S. gas-turbine type test; four years ago a Goblin completed 1,000 hr of simulated combat sorties without attention, and can fairly claim to be the world's most reliable turbojet.

The original R.A.F. Goblin 2 had a maximum thrust of 3,100 lb at 10,200 r.p.m.; the present Goblin 3 has a Lucas fuel system, diffuser cascades, and is up-rated to 3,350 lb by increasing r.p.m. to 10,750; the Mk 35 export engine, which is the engine in biggest production, runs at the same speed as the Mk 3, but has a smaller nozzle and so runs hotter to give 3,500 lb thrust.

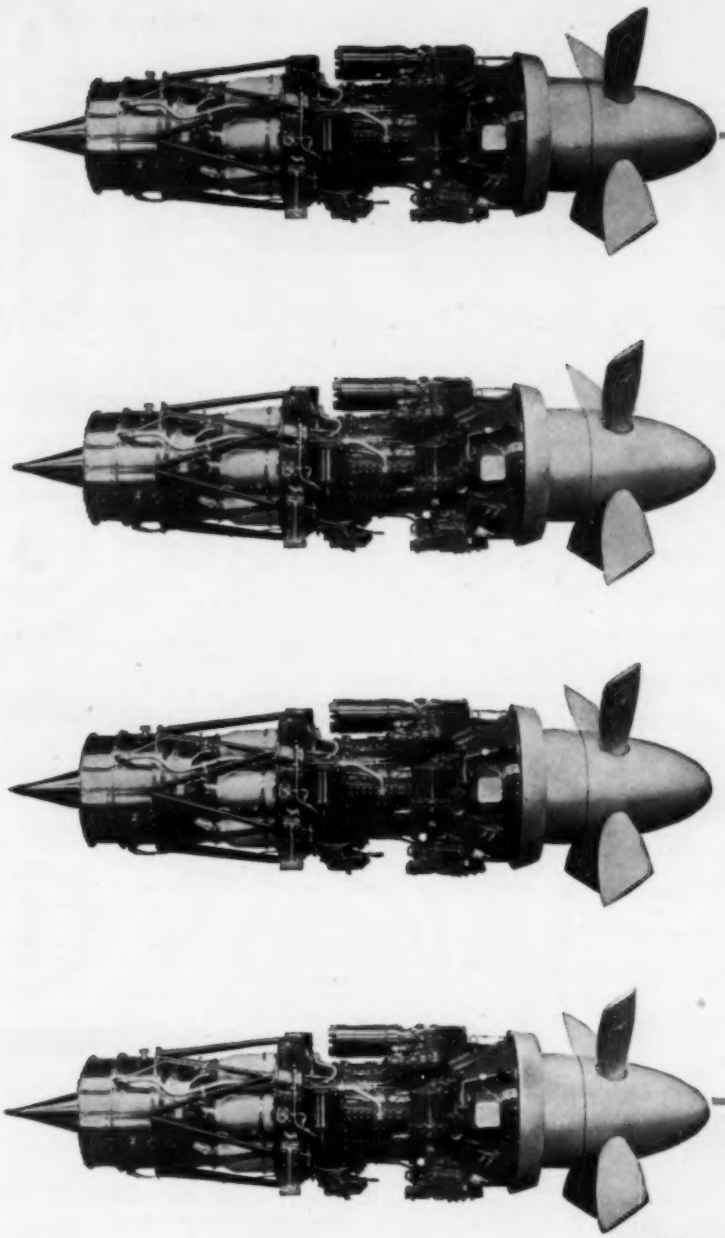
Ghost. Following the Goblin in layout in that it has a single-sided, direct-entry centrifugal compressor, the Ghost has a considerably greater mass flow and pressure-ratio. Two unusual features of the engine are the manner in which the ten cans are fed by twenty diffuser outlet ducts, and the fact that the fuel system works at no less than 2,000 lb/sq in.

The Ghost was the first turbojet to receive an A.R.B. civil certificate, and has flown over 100,000 hr in Comets, with a B.O.A.C. overhaul period of 750 hr. The civil Ghost 50 exists in four forms: Mk 1 without water/methanol injection and with a rating of 5,050 lb thrust; Mk 2 as illustrated; Mk 3 with a higher wet rating of nearly 6,000 lb; and Mk 4 as Mk 2 without w/m injection. The engine most commonly found in service is the Ghost 103, virtually identical with the Ghost 48 described under the Italian Fiat company. Compared with the single-intake Ghost, the Ghost 48 and 103 have a slightly reduced rating of 4,850 lb. There are very considerable detail differences between the civil and military Ghosts, and some 60 per cent of the original engine was redesigned to fit it for extended service on the airlines, at which hours are logged far more rapidly than in fighter service.

Afterburning Ghosts can give up to 30 per cent augmentation, within the limits of the Venom tail-pipe, and development is vigorously proceeding on both two-position, and fully variable, nozzles. References to the Ghost are made under Fiat (Italy), Flygmotor (Sweden), SNECMA (France) and Sulzer (Switzerland).

Gyron. All that can officially be said about this engine is that it is to be a large, axial-flow turbojet with a thrust greater than that announced for any other engine. In the first instance, at least, it will be used in supersonic applications. The second sentence provides the key to the *raison d'être* of this engine; a brief consideration of the pressures and temperatures inherent in such applications makes it fairly evident that the Gyron will be exceptionally robust, as well as being almost entirely of steel.

It will be interesting to see whether it is a two-spool engine or not; the trend is in that direction, but it should not be forgotten that supersonic ram-pressure lowers the optimum compression ratio so that a simpler compressor can be used, albeit at some low-speed penalty. But it has also been stated that the Gyron would be suitable for bombers and transports, and these considerations would not apply to the latter aircraft. Initially a private venture, the Gyron is being developed against an M.o.S. contract.



4 Elands =

12,000 e.h.p.

6,300 lb. weight

28 sq. ft. frontal area

designed and developed by

NAPIER

To take simple arithmetic a stage further, 4 Elands, for inter-city work especially, add up to higher payload, lower specific consumption, lower direct operating costs—in other words, superior operating economics.

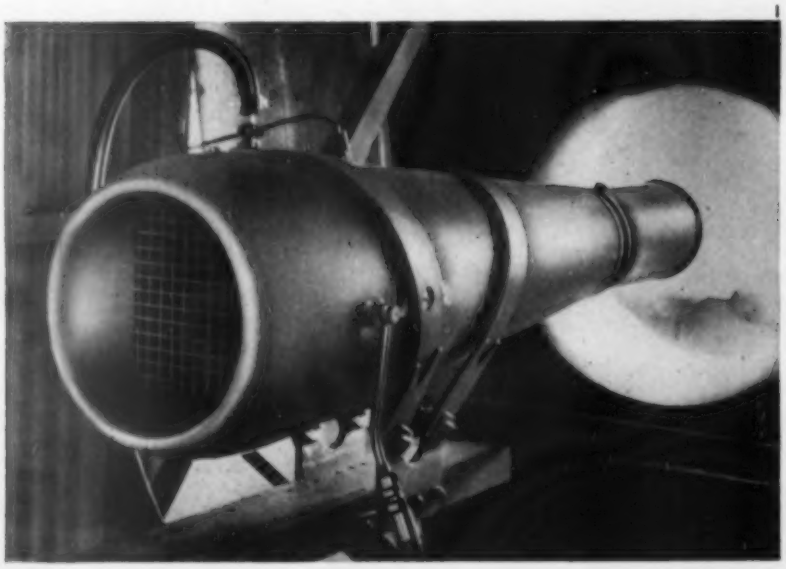
D. NAPIER AND SON LIMITED · LONDON · W.3

NIMONIC 75

in the SAUNDERS-ROE PULSE JET

With an operating cycle of 120 explosions per second, the Saunders-Roe pulse-jet unit glows red-hot after only a few minutes' running. Because operating conditions are so severe, Nimonic 75 is used for the combustion chambers. This nickel-chromium alloy, because of its resistance to scaling and oxidation at high temperatures, has for many years been used for the combustion chamber linings of most British gas turbines. Nimonic* 75 is now available to solve problems of materials in high-temperature construction.

* *Nimonic is a registered trade mark.*



Write for free copies of technical literature on properties and fabrication.

HENRY WIGGIN & COMPANY LIMITED

Wiggin Street · Birmingham 16

Aero Engines 1954 . . .

Super Sprite. The first de Havilland a.t.o. rocket was the Sprite, originally intended for the Comet. This engine set the pattern: it was a "cold" unit obtaining thrust by the dissociation of high-test peroxide when mixed with a permanganate solution. The Super Sprite works on the same principle, but blows the peroxide through a fixed catalyst; as a result the exhaust is no longer brown. In addition the Super Sprite consumes hydrocarbon fuel from the main aircraft tanks, which burns in the liberated oxygen in the exhaust. The peroxide is blown from the large tank by the compressed-air bottles ranged around the unit. It is in production as an assisted-take-off unit.

Fairey. *The Fairey Aviation Co., Ltd., Hayes, Middx.* In addition to their better-known work, the Fairey company have done a lot of research into helicopter tip-drive propulsion, the principal results of which are the Jet Gyrodyne, the static test rig with gas supplied by two Darts and the forthcoming Rotodyne. In addition, the company have carried out much development into the field of liquid-fuel rockets; the only real evidence of this which can be published is the Beta II motor, made to the design of the R.A.E. Rocket Propulsion Department at Westcott. The Beta II was very German, using 80 per cent hydrogen peroxide and "C-fuel" fed by a turbo-pump, the unit having a thrust of 2,500 lb.

Napier. *D. Napier and Son, Ltd., London W.3.* Long famous for high-quality piston engines, Napiers are now concentrating on gas-turbine aero engines, although the unique Nomad also involves a piston engine. In addition to development of the engines described below, the company are in production with the Rolls-Royce Avon at their works at Netherton, Liverpool.

Eland. This extraordinarily light and compact single-shaft turboprop is already at an advanced stage of development. Napiers themselves have developed much of the associated equipment, such as the fuel-metering unit and interlinked r.p.m./airscrew governor, and also the patented ignition system which gives outstanding starting and re-lighting.

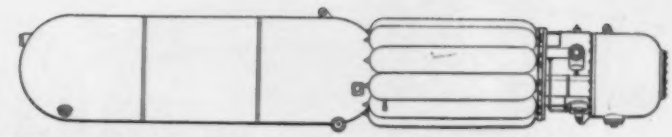
Other features are the massive central mounting ring, to which is attached a tubular framework supporting the turbines, and a special locating system which ensures exceptional accuracy in assembling the main rotating assembly. Aluminium-bronze compressor rotor blades and hollow turbine nozzle blades are used. Although initial trials will be made in a fixed-wing aircraft (in the near future) a special version of the Eland will power the Fairey Rotodyne.

Nomad. There have been several different types of Nomad, and each succeeding version has been smaller, lighter and more powerful than its predecessor. The NNm.6 works on the following principle: the gas-producer section consists of a highly-supercharged, two-stroke, compression-ignition engine, with twelve horizontally-opposed cylinders with sleeve valves. This unit provides a flow of gas suitable for a multi-stage turbine which is, in turn, geared to the main airscrew reduction gearbox *via* an infinitely-variable-ratio drive. In addition, the turbines drive an axial compressor which supercharges the reciprocating engine. The Nomad burns kerosine or diesel oil, with direct injection, and has a single-lever master control. The thermal efficiency and specific consumption are both significantly better than values recorded with any other aero engine. Various applications are envisaged, and flight trials will begin at the company's flight development establishment at Luton in the near future. A full description of the Nomad will be published in an early issue.

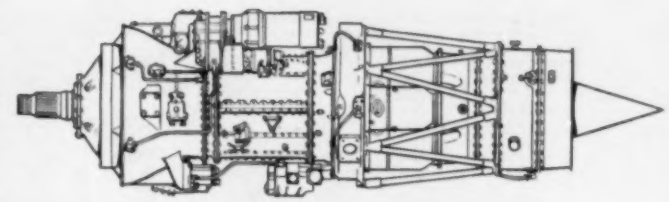
Oryx. Still on the secret list, the Oryx is a turbo gas-generator used for supplying a flow of hot gas which can be used in two ways. The first application is with the Oryx mounted in the fuselage of the Percival P.74 helicopter, and supplying gas through large ducts up the sides of the cabin to exhaust to atmosphere through tip nozzles on the rotor blades. It is also possible to use the Oryx in a fixed-wing machine, with the gas driving a power turbine mounted remote from the main power unit.

Putting two and two together, it seems likely that the Napier gas turbine which would power the Percival P.87 twin-engine transport would, in fact, be a version of the Oryx.

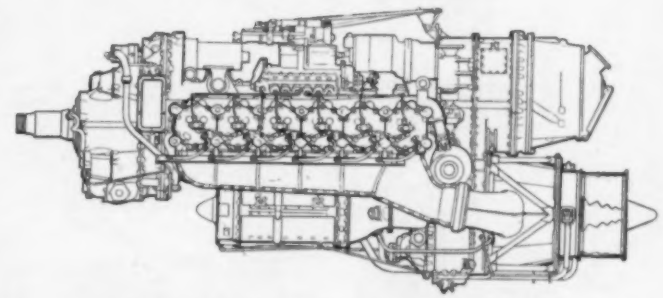
Rolls-Royce. *Rolls-Royce, Ltd., Derby.* For fifty years the name Rolls-Royce has meant engineering perfection, and it is not to be wondered that its influence stretches to the ends of the earth. Out of a wide range of products, gas-turbine aero engines account for well over 90 per cent of the company's total sales, and their leadership in this field dates back to 1941 when work began on turbojets of Whittle-type layout. Since then, a variety of "River-class" engines has appeared, and their production has increased year by year and at present involves at least 12 large factories, eight of these belonging to companies other than Rolls-Royce, and six being overseas.



de Havilland Super Sprite DSSp.1, a.t.o. rocket using high-test peroxide and a hydrocarbon fuel. Diameter, 19.5in; length, 117.5in; empty weight, 600 lb; total impulse, 120,000 lb-sec; maximum thrust, 4,000 lb.



Napier Eland single-shaft turboprop. Nine-stage compressor, six combustion chambers and two-stage turbine. Diameter, 36.1in; length, 104.5in; dry weight, 1,575 lb; pressure ratio, 7.0 : 1; maximum power, 2,690 s.h.p. plus 825 lb thrust, giving 3,007 e.s.h.p. at 12,500 r.p.m. with s.f.c. of 0.626 lb/hr/e.s.h.p.; cruising s.f.c., 0.452 lb/hr/e.s.h.p. at 35,000ft.

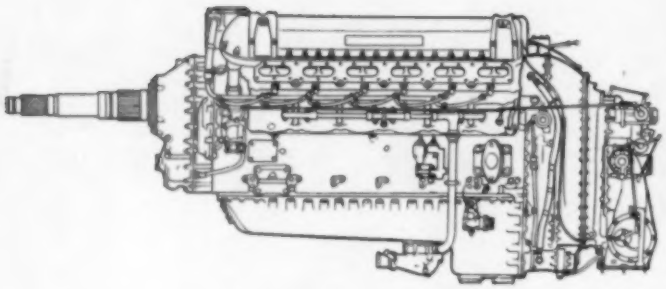


Napier Nomad NNm 6 compounded gas turbine/diesel engine. Two-stroke, liquid-cooled piston engine with 12 sleeve-valve cylinders, coupled with axial compressor and exhaust-gas turbine, all delivering power at single airscrew shaft. Width, 58.5in; height, 53in; length, 119 in; dry weight, 3,580 lb; maximum power, 3,050 s.h.p. plus 320 lb thrust, giving 3,135 e.s.h.p.; s.f.c., 0.33 to 0.35 lb/hr/e.s.h.p. over a wide range of powers and speeds.

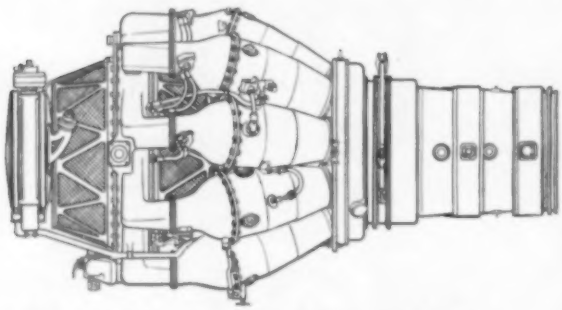
The Derby works includes the head office of the company's aero-engine division, the main design and development offices and a large factory turning out Avons, Darts and other engines. Other establishments include Barnoldswick (production of prototype and development engines), Sinfin (research and development, and production and experimental testing), Hucknall (airfield and flight testing), Mount Sorrel (sheet-metal factory), Ilkeston (production of Griffon power plants), Hillington (Avon production and repair, and stripping and assembly of piston engines), Larkhall and Blantyre (both on piston-engine repair work), and East Kilbride (Avon production and Derwent repair).

In addition, Avons are in production by D. Napier and Son at a Liverpool factory; by the Bristol engine division at Filton and by the Standard Motor Company at Coventry. Other companies manufacturing engines of basic Rolls-Royce design are Hispano-Suiza (France), Fabrique Nationale (Belgium), Svenska Flygmotor (Sweden), Commonwealth Aircraft (Australia) and Pratt and Whitney (U.S.A.). Rolls-Royce of Canada, Ltd., is also manufacturing engines, and all these companies are dealt with elsewhere. Rolls-Royce are also building a factory in Venezuela to service Canberra and Comet engines, and another in Australia to service and overhaul all their gas turbines in the Pacific area. The company is also a party to an agreement with the American firm of Westinghouse, involving some exchange of information and personnel, and manufacturing and sales rights if the latter are required.

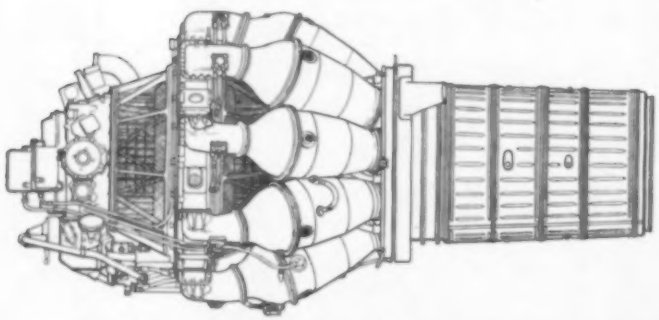
Merlin. About 150,000 of these 27-litre vee-twelve engines



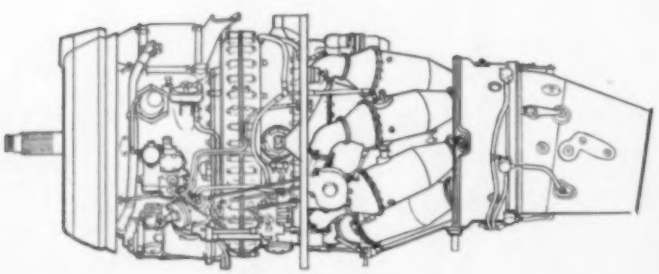
Rolls-Royce Griffon 57 12-cylinder, poppet-valve, pressure liquid cooled, 60-deg vee piston engine, geared to contra-rotating airscrew shafts and fitted with a fuel-injection pump, two-stage supercharger and intercooler. Bore, 6in; stroke, 6.6in; swept volume, 2,239 cu in (36.7 litres); width, 32in; height, 41.5in; length, 83.6in; dry weight, 2,090 lb; maximum power, 2,455 b.h.p. at 2,750 r.p.m. at 25 lb boost at sea level, with water-methanol injection.



Rolls-Royce Darwent RD.8 turbojet. Single double-sided centrifugal compressor, nine combustion chambers and single-stage turbine. Diameter, 43in; length, 83.1in; dry weight, 1,280 lb; mass flow, 63.9 lb/sec; pressure ratio, 4.1:1; maximum thrust, 3,600 lb at 14,700 r.p.m. with s.f.c. of 1.01 lb/hr/lb.



Rolls-Royce Nene 102 turbojet. Single double-sided centrifugal compressor, nine combustion chambers and single-stage turbine. Diameter, 49.5in; length, 96.8in; dry weight, 1,620 lb; mass flow, 90 lb/sec; pressure ratio, 4.5:1; maximum thrust, 5,100 lb at 12,500 r.p.m. with s.f.c. of 1.02 lb/hr/lb.



Rolls-Royce Dart 505 single-shaft turboprop. Two single-sided centrifugal compressors in series, seven combustion chambers and two-stage turbine. Diameter, 37.9in; length, 95.1in; dry weight, 1,030 lb; mass flow, 20 lb/sec; pressure ratio, 5.5:1; maximum power, 1,400 s.h.p. plus 365 lb thrust, giving 1,515 e.s.h.p. at 14,500 r.p.m. with s.f.c. of 0.83 lb/hr/e.s.h.p.

Aero Engines 1954 . . .

were built, and they played the dominant rôle in establishing Allied combat superiority in World War 2. Today it is the transport Merlin which is more important, and many are still in airline service. The single-stage Merlin is used in the York and two-stage Merlins power North Stars and Argonauts, the latter being arranged as self-contained power plants with special noise-damping exhaust systems.

Griffon. Slightly larger than the Merlin, some thousands of Griffons are in military and naval service, and production is continuing for the Shackleton.

Derwent. Present Derwents (the RD.8 is most common) are scaled-down Nenes; they have hardly changed since 1948, when steel compressor rotating guide vanes were adopted. In the Meteor, Derwent flight time had reached the tremendous total of 2,150,000 hr early last month—possibly more than for any other engine. Production continues.

Nene. Long used as a standard power unit in foreign fighters, Nenes are now serving in the Royal Navy's Attacker and Sea Hawk, with electric and cartridge starting respectively. In various developed forms the Nene has been made in America, France, Russia and the Argentine. In Australia and Canada it is still being made, and details of these engines are given in those sections. (All the first batches of Canadian Nenes are being made at Derby.)

Dart. A highly successful civil engine devoid of any military background, the Dart is famed as the power unit of the Viscount. The RDa.3s now in service all have shrouded turbine blades and a two-piece compressor shaft. Except for some B.E.A. engines, high-energy ignition is fitted; a water/methanol system is also standard. Now coming into production for Viscounts now on order is the RDa.6, in which a new reduction gear and other internal improvements make possible a maximum rating of 1,500 s.h.p. at increased r.p.m. There is also the completely new RDa.5, with an even greater design rating, scheduled to power the Viscount 800-series.

New Turboprop. It can be stated that development is very well advanced for a new, and extremely compact, civil turboprop. At present a private venture, it will initially have a rating of about 2,500 s.h.p., which should allow great room for development.

Avon. Britain has many rivers bearing this name, which now identifies the largest family of high-power turbojets in the world. The Avon was begun shortly after the war, when it was seen that centrifugal turbojets much bigger than the Nene would be likely to have prohibitive diameters. Not a great deal was known about axial compressors at that time, and Rolls-Royce needed about four years to get the first family of Avons right. These went into production in 1950 at a rating of 6,500 lb, for the Mk 2 Canberra. An unusual feature of these engines is the pneumatically actuated row of variable-incidence inlet guide vanes, and the compressor casing carries six bleed-valves which are open during starting and close only as pressure builds up. The prototype RA.2 weighed 2,400 lb and gave 6,000 lb thrust while the production RA.3 was 125 lb lighter.

The second basic type to go into production was the RA.7, which started a 7,500 lb family of Avons in 1952. First of the "hot nose" Avons with full all-weather protection, the RA.7 type has a power/weight ratio even better than that of the original production series, in spite of the fact that the engine has been re-stressed to accept the loads imposed at transonic speeds. This type of engine is in large-scale production for fighters and bombers. A variant of the series is fitted with an afterburner of Rolls-Royce design, with a two-position nozzle, giving a re-heat thrust of 9,500 lb (27 per cent augmentation). An offshoot of this family is the civil 500-series, of which the Comet 2 engine is illustrated. Features of these civil Avons are the big ports for cabin-air bleed-off, the large electric starter, full all-weather protection, a Hardy-Spicer coupling flange for a remote gearbox, a high-energy ignition system (no torch igniter pipes can be seen) and synchronization equipment.

Progenitor of the finest series of Avons yet achieved is the RA.14, which first ran in 1952 and yet was being delivered in quantity last summer. This Avon family shows much redesign, and it incorporates all the experience gained in the period 1947-50 regarding blade and compressor theory and combustion systems. With the best thrust/weight and thrust/frontal area ratios of any turbojet, the RA.14 clearly has a longer compressor than have previous Avons, and also has a true annular combustion chamber, the latter being essential in order to accept the huge mass flow without increasing engine hoop diameter; actually, these latest Avons are slimmer, as the dimensions reveal. The RA.14 itself appears to be a wing-buried engine, owing to the fact that the accessories are mounted along the "corners." It has a type-tested rating of 9,500 lb, but much of its running—even installed—has been at ratings well into five figures, and the type-tested Avon figures may be expected to follow suit. A civil

branch of this family is already bearing fruit, and the Comet 3, which was to have had an early "civilized RA.14" (the 9,000 lb RA.16) will now have a much later Avon giving 10,000 lb.

Conway. The existence has been revealed of this entirely new type of power unit, the by-pass engine. Here, the excess air from an oversize low-pressure axial compressor is by-passed around the combustion chambers; the resulting engine has a far greater mass flow at a lower mean velocity than would a simple turbojet burning fuel at the same rate. Rolls-Royce have produced the Conway RCo.1, 2 and 3, and it may be assumed that the production Conway will be some years ahead of any similar engine; in fact, we know of no other by-pass engine apart from the Turbomeca Aspin (q.v.).

Saunders-Roe. *Saunders-Roe, Ltd., Osborne, East Cowes, Isle of Wight.* The company's helicopter division has developed two small pulsejets, initially intended for rotor tip-drive applications. Made of Nimonic 75, they have completed some quite lengthy running, using pool petrol or bottled propane as fuel. The 45 lb-thrust unit illustrated on this page has now largely given way on the bench to a unit about 10in diameter with a thrust of 120 lb.

CANADA

Avro Canada. *A. V. Roe Canada, Ltd., Gas Turbine Division, Malton, Ontario.* The British Hawker Siddeley Group took over the Victory aircraft factory near Toronto in 1945 to form Avro Canada, and the following year the Canadian firm took over the Canadian government organization Turbo Research, Ltd., to form the nucleus of an engine company. By 1947 the Chinook axial turbojet had been developed, and this was followed by the much bigger Orenda, which first ran in 1949. In 1952 the company's superb 700,000 sq ft factory was built, and its staff of over 5,000 have since been making Orendas at something like 125 per month. To make sure of the future, research and development has been aiming at a number of impressive developments; of these, only the existence of a new turbojet can be mentioned.

Orenda. The first production engine designed in the British Commonwealth—outside Great Britain, that is—is, remarkably enough, this big and complicated turbojet. The name means "the source of all power," and refers to an Indian deity. The Orenda is a single-shaft engine and its compressor has been steadily developed to give better output. The first deliveries from Malton gave about 6,000 lb thrust, and have powered Avro Canada CF-100 Mk 3s. The Orendas now in production are the 8, 9 and 10, of 6,500 lb thrust, and these are all-weather engines, de-iced by an alcohol spray whirled from the spinner cone. The engines are used in CF-100 Mk 4 and Sabre 5, and the 1,000th Orenda was delivered early this year, on schedule. The Orenda 11 has a two-stage turbine and gives about 7,000 lb thrust with a specific fuel consumption well under unity. A Solar afterburner is fitted to some engines, boosting the thrust to about 8,500 lb.

Waconda. This is reported to be the name of a new axial turbojet now being developed against a Government contract. The Malton test cells were designed to accept a 15,000 lb thrust engine, and prototype engines of this calibre are probably being built, possibly for installation in the Avro Canada CF-105 all-weather fighter.

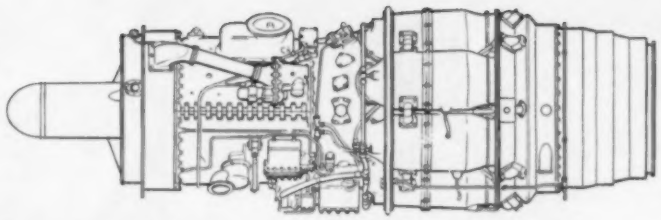
Canadian Pratt and Whitney. *Longeuil, Montreal.* Here the latest version of the R-1340 Wasp—the engine designed back in 1925—is in large-scale production for Canadian and American T-6 Texans (Harvards).

Rolls-Royce. *Rolls-Royce of Canada, Ltd., Montreal.* After a long period of spares production and Merlin servicing, the manufacture of complete Nene turbojets is to be undertaken in a new factory which is fully tooled and is now assembling Nenes from British parts. The Canadair Silver Stars (T-33AN) will need about 900 Nenes; the majority will be built at Derby but final deliveries will come from Montreal. The Nene 10 is identified by a projecting electric starter and a mass of flexible hosing. A Lucas fuel system and Rotax high-energy ignition are standard.

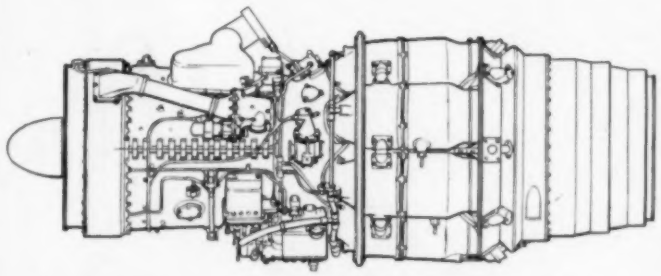
AUSTRALIA

Commonwealth. *Commonwealth Aircraft Corpn., Pty., Ltd., Lorimer St., Port Melbourne.* During the war, this corporation licence-produced the Pratt and Whitney R-1340 Wasp and R-1830 Twin Wasp. At the end of the war, the engine factory at Lidcombe, N.S.W., switched to production of the Merlin 102 for Mustangs and Lincolns, and is now working on the engines described below.

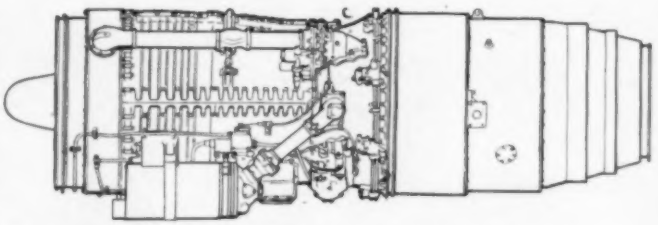
Nene 2-VH. This generally resembles the British engine but, as the weight had to be reduced, the compressor case is made of



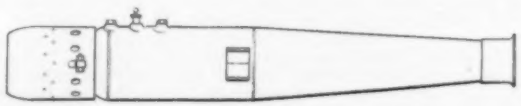
Rolls-Royce Avon RA.7 turbojet. Axial compressor, eight combustion chambers. Diameter, 42.2in; length, 110in; dry weight, 2,460 lb; maximum thrust, 7,500 lb at 7,800 r.p.m. with s.f.c. of 0.92 lb/hr/lb. With an afterburner this engine gives 9,500 lb thrust.



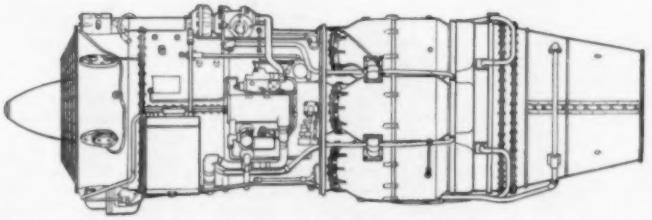
Rolls-Royce Avon 503 commercial turbojet. Axial compressor, eight combustion chambers. Diameter, 42.2in; length, 102.6in; dry weight, 2,242 lb; maximum thrust, 7,150 lb at 7,800 r.p.m. with s.f.c. of 0.89 lb/hr/lb.



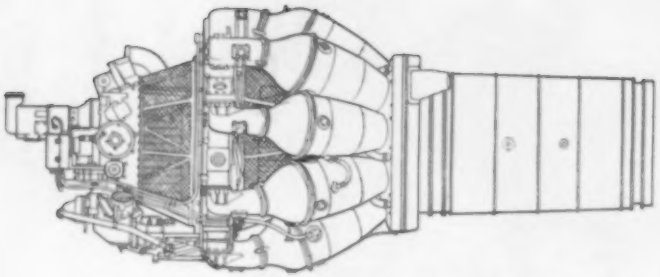
Rolls-Royce Avon RA.14 turbojet. Axial compressor and annular combustion chamber. Diameter, 41.5in; length, 113.3in; dry weight, 2,860 lb; maximum rated thrust, 9,500 lb with s.f.c. of 0.84 lb/hr/lb.



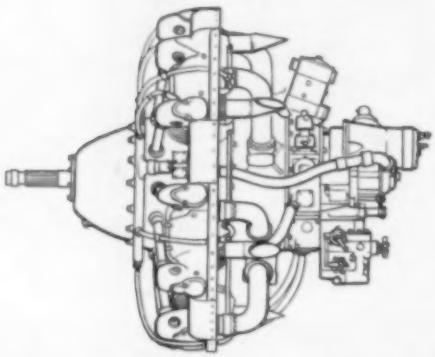
Saunders-Roe 45-lb pulsejet. Flapper-valve pulsejet with design frequency of 45 c.p.s. Diameter, 5.5in; length, 47.5in; dry weight, 15.5 lb; maximum thrust, 45 lb at sea level.



Avro Canada Orenda 8 turbojet. Ten-stage axial compressor, six combustion chambers and single-stage turbine. Diameter, 42in; length, 121.3in; dry weight, 2,700 lb; mass flow, 110 lb/sec; pressure ratio, 5.7:1; maximum thrust, 6,500 lb at 7,800 r.p.m. with s.f.c. of 1.00 lb/hr/lb.



Rolls-Royce of Canada Nene 10 turbojet. Single double-sided centrifugal compressor, nine combustion chambers and single-stage turbine. Diameter, 49.5in; length, 104in; dry weight, 1,610 lb; mass flow, 90 lb/sec; pressure ratio, 4.5:1; maximum thrust, 5,100 lb at 12,500 r.p.m. with s.f.c. of 1.00 lb/hr/lb.



C.A.C. Cicada seven-cylinder, air-cooled radial, with small 10:1 blower and 0.8:1 reduction gear. Injection-type carburettor. Bore, 5.375in; stroke, 5in; swept volume, 795 cu in (13.1 litres); diameter, 46.5in; length, 58in; dry weight, 770 lb; maximum power, 450 h.p. at 2,600 r.p.m. at sea level.

Aero Engines 1954 . . .

magnesium. The unit is installed—with "elephant-ear" intakes—in the D.H. Vampire 30, and is now giving way to the Avon.

Avon. Production of the Rolls-Royce Avon is now in full swing, for the Commonwealth CA-27 Sabre and D.A.P. Canberra. The engines now being delivered correspond to RA.3s, but these will be replaced by RA.7s in a few weeks.

Cicada. Basing their work on the Pratt and Whitney engines made during the war, the Commonwealth engineers have developed this all-Australian power unit, which is to be the standard engine of the Winjeel trainer from No. 30 onwards. The engine is geared and supercharged, and has a Bendix updraught injection-type carburettor. As the drawing shows, the airscrew shaft is slightly above the engine centre-line.

U. S. A.

Aerojet. *Aerojet Engineering Corpn., Azusa, California.* A subsidiary of the General Tire and Rubber Co., Aerojet are specialists in rocket motors, their production of which, for the smaller-sized units, is the largest in the world. All their early work concerned solid-fuel RATOG units, but liquid-fuel motors are now being developed and are in production. Applications include take-off assistance, missile propulsion through air and water, and extreme-altitude research motors.

The latest RATOG units are a range of re-usable plastic bottles with Niafrak nozzles. The U.S.A.F. are using integral, built-in bottles, and the 14AS-1000 G-1 (1,000 lb thrust for 14 sec) is a recent a.t.o. unit approved by the C.A.A. In other fields, the Aerobee sounding rocket, which has reached 86 miles altitude, uses two fuels fed from welded chambers by helium pressure; the Douglas Nike ground/air missile has an Aerojet liquid-rocket motor; the Convair Terrier has a solid-fuel motor; the Firestone Corporal has an Aerojet liquid-fuel rocket; and the latest development is a large oxy-hydrogen rocket for missiles, this being the first use of these fuels on such a scale.

Allison. *The Allison Division of General Motors Corpn., Indianapolis 6, Indiana.* After making many thousands of V-1710 piston engines, the company entered the gas-turbine field in November 1945 when they assumed responsibility for the General Electric I-40 turbojet. The following September they took over the G.E. TG-180 axial engine, and over 25,000 of these basic types have since been built as the J33 and J35. Shortly after the war, Allison embarked on the development of a turbo-prop of their own design (the T38), and progressive development of this engine, together with the big J71 turbojet, will be the company's main task in the immediate future. There are indications, however, that the company's huge output of 1952-3 will be the highest for some time to come.

J33. The only American-designed centrifugal turbojet in service, this has a family tree going back to the Whittle engines; as noted above, it is of basic G.E.C. design. The engine illustrated is typical of the original J33; in the form shown it powers the Lockheed T-33 and F-80, and the J33-A-33 (afterburner, 7,000 lb thrust) powers the F-94A and B Starfire. One J33-A-35 in Korea completed 1,200 combat hours with three field-repair cycles, there being one 800-hr period without more than routine servicing.

Allison have developed a revised J33 able to pass a mass flow of 115 lb/sec at 11,800 r.p.m. This more powerful family is used in the F9F Panther (J33-A-16, 5,850 lb thrust dry) and, with an afterburner, in the XF-92A (J33-A-29, 8,200 lb thrust). The J33-A-16A, of 6,350 lb dry rating, is the most powerful "basic" J33; this engine powers the Cougar, and four Cougars of squadron VMF-314 recently flew 2,404 hr in one month, so the J33 cannot give much trouble. It is also much used as a missile engine (it costs only £14,000) in such aircraft as the Matador (J33-A-37) and Regulus.

J35. Originally the General Electric TG-180, the J35 makes instructive comparison with G.E.'s own J47. Although found only in the F-89 Scorpion (with afterburner) and the straight-wing F-84 Thunderjet, these two applications alone have absorbed over 12,000 J35s. The original engine was rated at 4,000 lb thrust, but Allison modified it in the same manner as they did the J33, and the present engines have a bigger mass flow and a thrust which varies from engine to engine between 5,200 and 5,600 lb.

The reheat engine has a Solar detachable afterburner, with pneumatically actuated eyelids; one such, a J35-A-35, is illustrated on p. 436. The latest J35s have retractable intake screens and full anti-icing; about a year ago all J35s were re-equipped with General Electric capacitor-discharge ignition. Production is now tapering off.

J71. Allisons have found this impressive turbojet rather a hard nut to crack. First run in 1950, it is a high-compression, all-steel engine, very well made and fitted for all-weather operation. It has its own integral oil and hydraulic systems, the latter being used to actuate nose-intake screens and doors and a tailpipe bullet which varies the propulsive nozzle area—a very unusual feature these days. It may be that the J71 ought to be a two-spool engine; it is proving rather heavy and inflexible and is taking longer to develop than it should.

The basic engine is rated at 9,700 to 10,000 lb according to sub-type, and 14,000 lb is available with an afterburner. Major production of the J71-A-9 is now in hand for the B-66 series, and other applications are the F3H Demon (A-2 with afterburner) and YF-105 (A-7 with high-altitude afterburner).

T38. Originally a single-shaft engine with no fewer than 19 compressor stages, the T38 has since been somewhat lightened and had two compressor stages removed. Both on the ground and in the XF-88B, T38s have done much testing of supersonic airscrews, with drive speeds of 2,000/2,500 r.p.m. It also flew in the Convair Turbo-Liner. A variant is scheduled to power the Piasecki YH-16A.

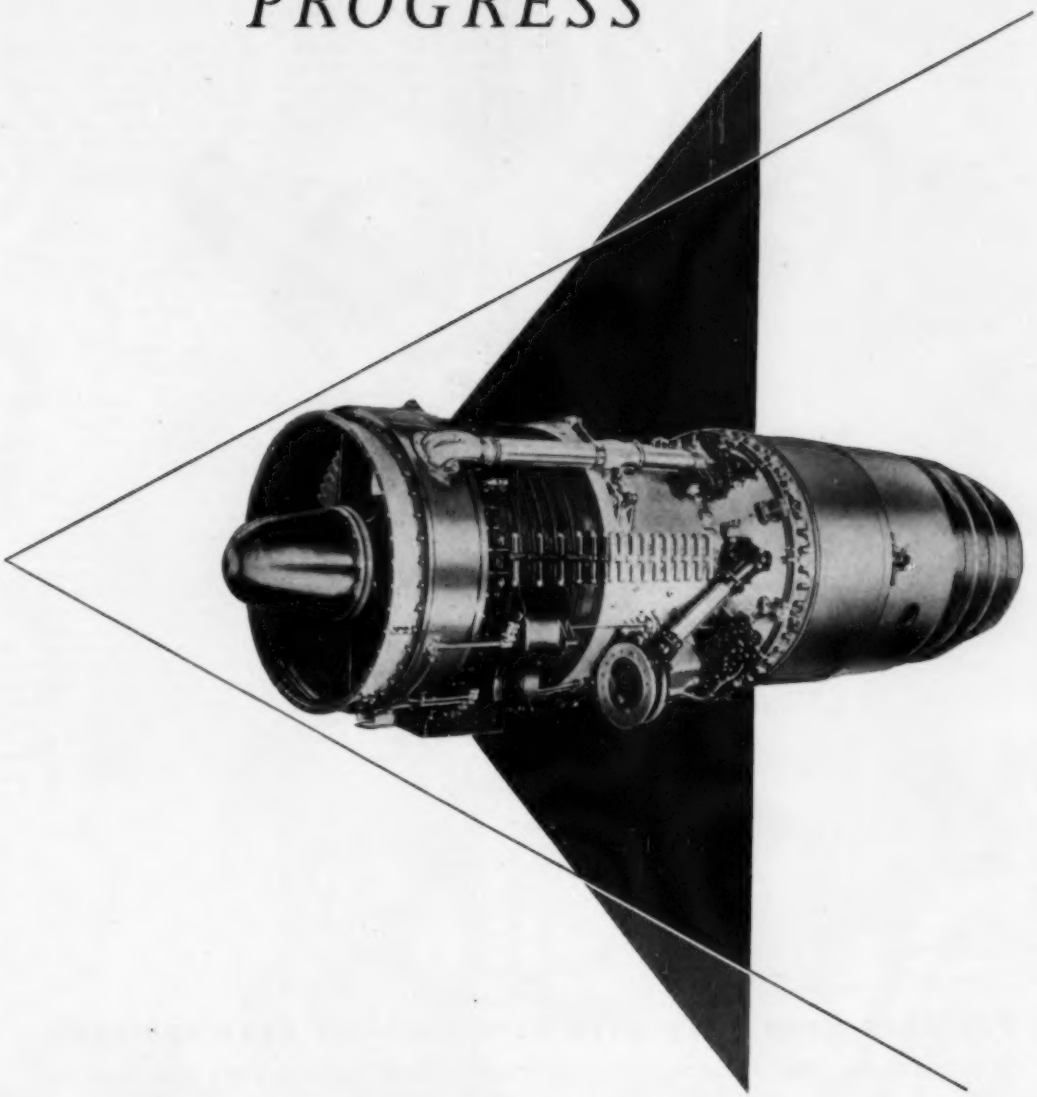
T40. Basically consisting of two T38 power sections, each driving both halves of a contra-rotating airscrew *via* a gearbox mounted well forward of the engine, the present T40-A-10, which powers the Tradewind, is much shorter and lighter than its predecessors. The primary-reduction gearbox and Aero-products electronic control system have both raised a great many problems, but now seem to be working satisfactorily. The engine is in production for the Tradewind, and it has also been selected for the first crop of vertical take-off prototypes.

T54. This engine consists of two T56 power sections coupled together, as are two T38s in the T40. Three T54s are about to be started on tests of three different types of supersonic airscrew, nose-mounted in Republic XF-84H test-beds.

T56. A turboprop of 3,750 h.p., the T56 bears a close resemblance to the T38. It is, however, a much neater engine, with fewer compressor stages and with an annular combustion chamber. Of all-steel construction, it has completed its pre-flight trials and is to fly shortly in the YC-135 (CV-340 test-bed). The T56-A-1 is already coming into production for the Lockheed C-130.

520-C-1. This projected turbojet version of the T38 has a

PROGRESS



Already the Avon engine has progressed from its initial thrust of 6,000 lb., to the 7,500 lb. thrust RA.7 with full anti-icing, the RA.7R with re-heat, and the RA.14 without re-heat, both of 9,500 lb. thrust.

ROLLS-ROYCE
Aero
ENGINES

ROLLS-ROYCE LIMITED, DERBY

"Cellon Finishes keep pace with aeronautical development"

A constant awareness of the new demands which aircraft manufacturers and designers will be asking of their materials; the advanced research equipment and technicians with which to anticipate these new demands; and the all-important factor of resistance to new lubricants are just some of the reasons why Cellon always have and always will dominate the field of Aircraft Finishes. And those who have established Britain's lead in world aeronautics development know full well the important part the finish plays at modern flying speeds. Proof? You'll find a Cellon Aircraft Finish on our most advanced planes!

CELLON AIRCRAFT FINISHES

CELLON LIMITED KINGSTON-ON-THAMES SURREY *Phone: Kingston 1234 (7 lines) Telegrams: AJAWB, Phone, Kingston-on-Thames*

Also manufactured in AUSTRALIA CANADA FRANCE HOLLAND NORWAY

CVS–752

Aero Engines 1954 . . .

design thrust of 1,870 lb with an s.f.c. of 0.927 lb/hr/lb. Production awaits a Navy trainer or target application.

Boeing. *Boeing Airplane Co., Seattle* 14, *Washington.* Boeing have had a gas-turbine section for over ten years, and an immense variety of items has been studied. After a Model 500 turbojet of about 200 lb static thrust had been run, a shaft-drive variant was made. This engine, originally Model 502, has since received development contracts for the U.S. Navy as the T50. Boeing have also developed ramjets, ever since the beginning of the Ground/Air Pilotless Aircraft project in 1946. G.A.P.A. has led the way to the F-99 Bowmarc. Another Boeing development is a civil/military reverse-thrust device.

T50. First flown in December 1951 in a Kaman K-5 helicopter, a number of different types of T50 have been developed; the drawing shows the fixed-wing 502-8, which has completed 30-hr evaluation in a Cessna L-19. The Doman helicopter company have stated that they are preparing a 250 h.p. T50 with higher compression. Earlier types of T50 have been used in a Kaman helicopter, and the engine is also in production for U.S.A.F. air-compressor units.

Continental. *The Aircraft Engine Division of Continental Motors Corpn., Muskegon, Michigan.* Manufacturers of automotive, marine and other engines, Continental have made air-cooled aero engines since 1928, to a total value of £393m. In 1952 a subsidiary company, Continental Aviation and Engineering Corpn., began a development programme on eight gas turbines of Turboméca design, for which Continental hold exclusive American manufacturing rights.

Of these, the Marboré is the J69 (below); the shaft-drive Artouste is being tested in an S-52 helicopter and a Cessna L-19B; and the Palouste is in production as the MA-1 to fill a £1.9m U.S.A.F. contract for ground-starter compressors.

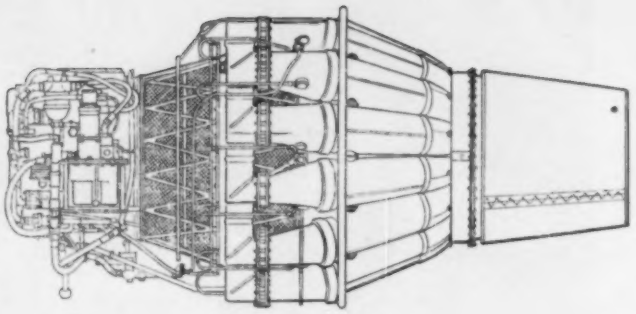
Piston Engines. Continental have a range of generally similar flat-four and flat-six, unsupercharged, direct-drive engines in production, with ratings from 65 to 300 h.p. Most have venturi carburettors, but the E-185 and 225 series (used in the Bonanza and Mentor) have low-pressure fuel-injection. The C-145, illustrated, powers the Cessna 170.

The R-975 radial engine was a standard power unit for heavy military vehicles and tanks until 1945, and a special version now powers the Piasecki HUP and H-25 helicopters. With slight variations in accessories, the helicopter R-975 can be used with the crankshaft in any position between horizontal and vertical; it has direct drive, a single-speed supercharger, and a two-barrel updraught injection-type carburettor. The engine illustrated powers the HUP-2 and H-25A; an earlier R-975, of 525 h.p., is used in the HUP-1 and Kaman HOK-1.

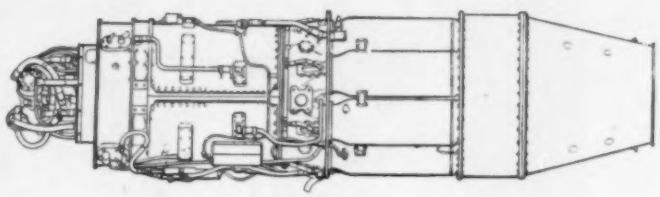
J69. The Turboméca Marboré 352 has been "Americanized" and put into large-scale production by Continental, the first major application being the Cessna T-37 twin-engined primary trainer. The J69 has American alloys, pipe- and bolt-threads, and some American equipment, such as a Bendix high-energy ignition system.

Fairchild. *Fairchild Engine Division of Fairchild Engine and Airplane Corpn., Farmingdale, Long Island, N.Y.* Apart from the large works at Farmingdale and Valley Stream, N.Y., the Fairchild Engine Division has opened a new plant at Roosevelt Field, N.Y., which is engaged on a secret £16m contract. Most of the company's work is of a secret nature, but "several unique types of military engine" are being developed. The J44 (below), the V-32-D-2 airborne auxiliary power unit, and major components of J47 and J73 turbojets are in mass production.

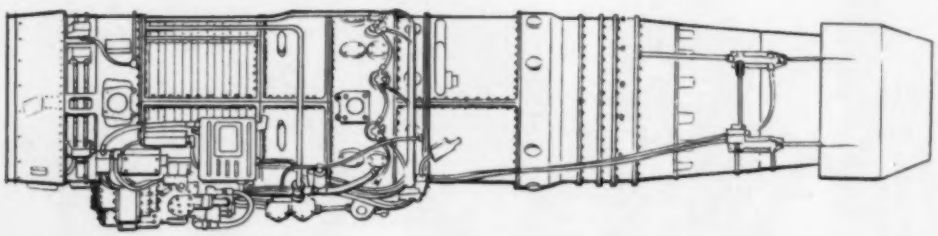
J44. The unique feature of this engine is its monocoque construction (it is, in fact, dubbed the "Monocoque"). A single outer case of steel sheet forms the pressure case and the shell supporting the compressor housing and exhaust section, while



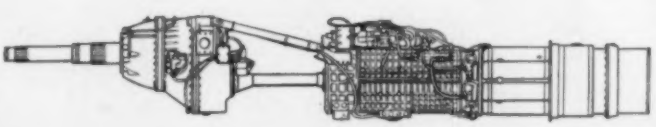
Allison J33-A-35 turbojet. Single double-sided centrifugal compressor, 14 combustion chambers and single-stage turbine. Diameter, 49.2in; length, 104.5in; dry weight, 1,795 lb; mass flow, 86 lb/sec; pressure ratio, 4.4:1; maximum thrust, 5,200 lb (5,400 lb with water injection) at 11,750 r.p.m. with s.f.c. of 1.12 lb/hr/lb.



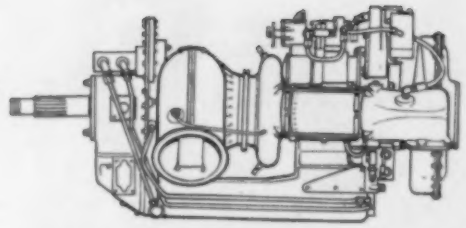
Allison J35-A-29 turbojet. Eleven-stage axial compressor, eight combustion chambers and single-stage turbine. Diameter, 37in; length, 146in; dry weight, 2,260 lb; mass flow, 95 lb/sec; pressure ratio, 5.5:1; maximum thrust, dry, 5,600 lb at 7,800 r.p.m. with s.f.c. of 1.05 lb/hr/lb.



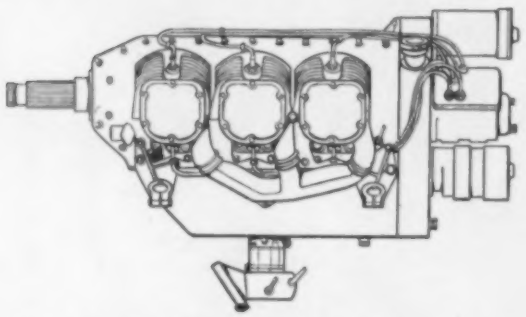
Allison J71-A-7 single-spool turbojet with short afterburner. Sixteen-stage compressor, cannular combustion chamber consisting of two-piece stainless-steel annular chamber housing 10 individual interconnected flame tubes, and three-stage turbine. Variable-area tailpipe; electro-mechanical control system; automatic intake shutters; air-turbine starter driving direct on to front of compressor. Diameter, 37in; length, about 210in; dry weight, 4,400 lb (non-afterburning engine, 4,100 lb); mass flow, about 172 lb/sec; pressure ratio, 8.75:1; maximum thrust, 14,500 lb with re-heat, or 10,000 lb thrust basic (11,500 with water injection), at 6,100 r.p.m. with s.f.c. (non-afterburning) of 0.898 lb/hr/lb



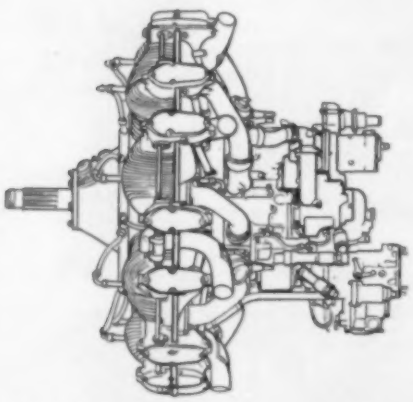
Allison T40-A-10 double turboprop. Each single-shaft power section has a 17-stage axial compressor, eight combustion chambers and four-stage turbine. Total width, 39in; height, 24in; length, 167in; dry weight, 2,550 lb; mass flow (total), 88 lb/sec; pressure ratio, 6.3:1; maximum power, 5,125 s.h.p. plus 830 lb thrust at 14,300 r.p.m. giving 5,525 e.s.h.p.; s.f.c., 0.63 lb/hr/e.s.h.p.



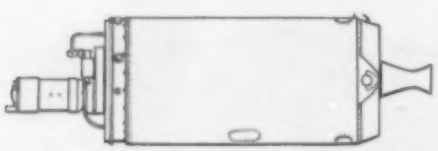
Boeing 502-8 (T50-BO-1) free-turbine turboprop. Single centrifugal compressor, two lateral combustion chambers, single compressor turbine and independent power turbine driving 10.9 : 1 reduction gearbox. Width, 23.2in; height, 27.3in; length, 46.8in; dry weight, as shown, 267 lb; mass flow, 3.6 lb/sec; pressure ratio, 3 : 1; maximum power, 210 s.h.p. plus 35 lb thrust, giving 224 e.s.h.p. at 37,500 compressor r.p.m., with s.f.c. of 1.3 lb/hr/e.s.h.p.



Continental C-145-2 horizontally-opposed, air-cooled, six-cylinder engine, ungeared and unsupercharged. Bore, 4.0625in; stroke, 3.875in; swept volume, 301 cu in (4.9 litres); width, 31.5in; height, 26.7in; length, 39.8in; dry weight, 257 lb; maximum power, 145 h.p. at 2,700 r.p.m.



Continental R-975-42 nine-cylinder, air-cooled, poppet-valve radial for helicopters, ungeared but supercharged and with injection-type carburettor (note: the valve-gear push rods lie behind the cylinders). Bore, 5in; stroke, 5.5in; swept volume, 973 cu in (15.9 litres); diameter, 45.5in; length or height (according to installation), 42.4in; dry weight, 730 lb; maximum power, 550 h.p. at 2,400 r.p.m. at 6.8 lb boost at sea level.



Fairchild J44-R-12 expendable turbojet. Single diagonal-flow (first centrifugal, then axial) compressor, annular combustion chamber with 12 fuel nozzles; single-stage turbine. Diameter, 22in; length, 75.7in as shown with nose accessory section; dry weight, completely bare, without fuel filter, or any accessories, 303 lb; pressure ratio, 2.5 : 1; maximum thrust, 1,000 lb at 15,780 r.p.m.; s.f.c., 1.65 lb/hr/lb.

Aero Engines 1954 . . .

the two latter components carry the main bearings. The compressor is a mixed- (or diagonal-) flow unit, with a cast light-alloy centrifugal inducer section and an axial rear section machined from a magnesium-alloy forging. The assembled compressor is splined to its drive shaft, and a bleed line communicates pressure from the compressor outlet to the oil tank (which is integral with the compressor housing) to blow oil into the two bearings. The whole engine is extremely simple and, bearing in mind its several missile and target applications, it is logical that it should be capable of being mounted on the tail of an airframe as an unsupported cantilever.

Franklin. *Aircooled Motors, Inc., Syracuse 8, N.Y.* Although Aircooled Motors did not begin aero-engine manufacture until 1938 their products have found wide acceptance in many countries. All Franklin engines are four- or six-cylinder horizontally-opposed units. About three out of four helicopters now flying are claimed to be Franklin-powered. Franklin engines have one-piece light-alloy cylinders with removable iron liners. Several of the designs have integral axial-flow cooling fans which, in conjunction with special air ducting, permit submerged installations in helicopters and other aircraft. The engine shown is the most important of the range, and it is found in the Bell 47-series and Hiller H-12-series. Some 2,500 of these helicopters are in use.

G.E.C. *Aircraft Gas Turbine Division, General Electric Company, Cincinnati 15, Ohio.* Long famed for their turbo-superchargers, G.E.C. were a logical choice when, in 1941, a company had to be selected to build the Whittle turbojet in the U.S.A. The original Whittle conception was developed into the 4,000-lb thrust I-40 (J33) in 1944 and the axial-flow TG-180 (J35) the next year. Responsibility for both the J33 and J35 was passed to Allison, and G.E.C. concentrated on the J47, over 20,000 of which have so far been delivered.

This vast company (aero engines are a small part of the whole) has extensive research facilities for all forms of aircraft propulsion. Last year a £650,000 laboratory was built near Schenectady for ramjet and general combustion research. Evendale, Lockland, Lynn and Schenectady are the main aero-engine plants and J47 production has exceeded 100 per week for some three years. Vertical assembly is practised, so saving floor space and achieving better alignment.

Rocket work is typified by the fact that the company have a 20,000-lb thrust fighter or missile engine ready for production, using non-critical materials and readily available fuels. The company is also a principal contractor to the U.S.A.F.'s Aircraft Nuclear Propulsion Project, the department being headed by D. Roy Shoults, the American jet engineer. A general engineering and consulting laboratory is another asset, and has done work on ramjet intakes and diffusers. A further very large section is that devoted to aircraft auxiliary power requirements, some of the developments being described on p. 436.

J47. This is an advanced refinement of G.E.C.'s first axial engine, the J35, which was passed to Allison in 1946. Development has been based on three main families, the C engines of 5,200 lb thrust, the D at 7,200 lb and the E at 5,800 lb. Of these, the C type, powering early Sabres and B-36s, is no longer in production.

The chief D engine is the J47-GE-17, for the F-86D. It is an all-weather engine fitted with a G.E. afterburner and a remarkable G.E. electronic control system; it also introduced a larger compressor and used fewer strategic alloys than did earlier engines.

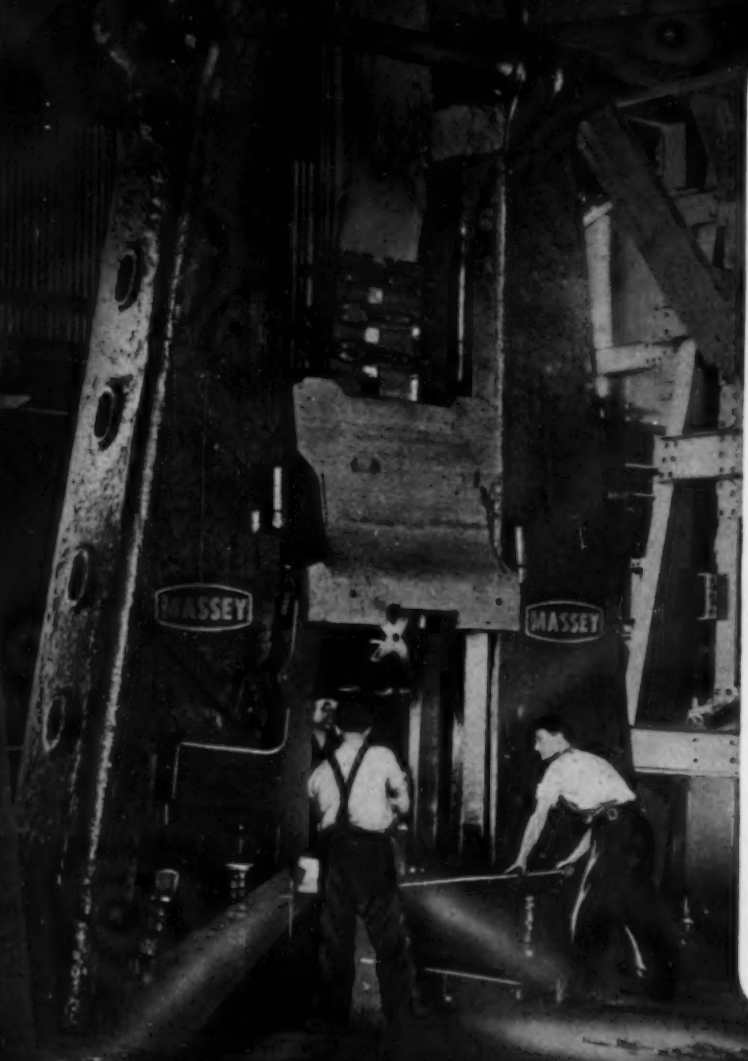
The important E range shows over 3,000 differences compared with earlier types, including a complete can redesign. In 1950 various types of E went into very-large-scale production, largely for the B-47 and F-86, the J47-25 being built by Studebaker at South Bend and Packard at Detroit and Utica. All are "hot-nose" all-weather engines, having 10 per cent more thrust, higher compressor efficiency, heated intake surfaces, retractable screens, improved high-altitude fuel and combustion systems and better s.f.c. High-energy, opposite-polarity ignition is also fitted, giving easy high-altitude re-lighting.

Owing to a gross under-estimation of the J47's life, it was found last year that about 2,000 too many had been ordered, and "cutbacks" exceeded £36m, most of this falling on the car firms.

All but the afterburning model are cleared for a 1,200-hr overhaul life, but how many engines reach this figure is uncertain. Production is now tapering off.

J53. This family of huge axial turbojets has completed much development running during the past five years, and the lessons learned have been incorporated in later large engines. With a mass flow usually near 260 lb/sec, some J53s have recorded thrusts approaching 20,000 lb, and an afterburning engine has given 23,750 lb. The majority have a 13-stage compressor (7.7 : 1),

TURBINE DISCS and COMPRESSOR WHEELS



for
WORLD-FAMOUS BRITISH
GAS TURBINE ENGINES

AVON
DERWENT
GHOST
GOBLIN
NENE
MAMBA
OLYMPUS
PROTEUS
PYTHON
SAPPHIRE

The large Drop Hammers of our Lincoln Forge produce a wide range of TURBINE DISC and COMPRESSOR WHEEL forgings in Heat Resisting Steels for the BRITISH AERO-ENGINE INDUSTRY

SMITH-CLAYTON FORGE LTD · LINCOLN · ENGLAND

C. C. WAKEFIELD & CO. LTD • GROSVENOR STREET • LONDON • W.1

Aero Engines 1954 . . .

annular combustion chamber of 44in diam and a two-stage turbine; maximum r.p.m. are about 5,800.

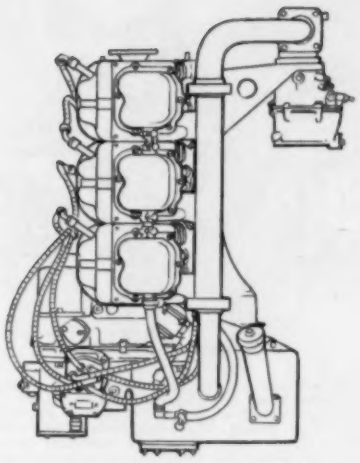
J73. Now rapidly being brought into large-scale production, the J73 gives nearly double the power of the J47, although it fits into the same space envelope and mounting brackets. A much greater mass flow has been achieved by moving the nose-mounted accessories to a point under the engine, and the flow has been accommodated in the combustion system by making the latter of the cannular type. The J73s embody every J47 advance and some additional features such as variable-incidence inlet guide vanes; all are all-weather engines, and some have afterburning. Apart from the F-86H, for which the J73-GE-3 is already in production, several new aircraft, some unmanned, are to use this engine.

J77. No information is available on this engine, beyond the fact that it is a large axial turbojet.

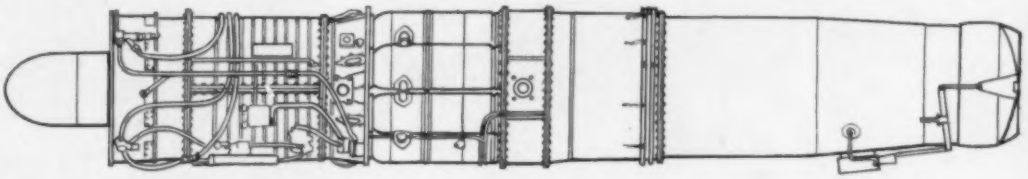
J79. Originally known as the X-24A, this is the nearest American counterpart to the Gyron. An all-steel axial turbojet of very massive construction, it is specifically intended for supersonic flight. As a result it has been found possible to employ a single-spool compressor, although the stator blading is of variable pitch. The design thrust is 15,000 lb dry, and an afterburner is being developed in parallel with the basic engine. It is to be the power unit of the Convair XB-58 supersonic delta bomber.

X-25. This fighter turbojet is in the early stages of development; it will be a very light, small-diameter engine giving 12,000 lb thrust dry.

T58. Illustrated in mock-up form on page 431, this axial turboprop has been designed to meet a U.S. Navy specification for an 800 h.p. helicopter engine. A free power turbine is employed, with a drive-shaft projecting at the rear of the engine between bifurcated tailpipes. G.E.C. hold a Navy development contract.



Franklin 6V4-178-B32 helicopter engine. Six horizontally-opposed air-cooled cylinders, direct drive, unsupercharged. Bore, 4.5in; stroke, 3.5in; swept volume, 335 cu in (5.5 litres); width across valve covers, 30.8in; width across carburettor (left to right in drawing), 30.3in; height, 38.2in; dry weight, 311 lb; maximum power, 178 h.p. at 3,000 r.p.m.

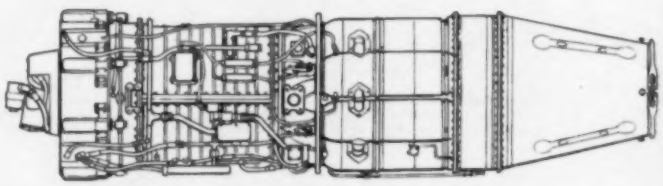


General Electric J47-GE-17 turbojet with afterburner. Twelve-stage compressor, eight combustion chambers and single-stage turbine; hot-air de-iced intake, afterburner with electrically actuated eyelids, and electronic control system. Diameter, 36.75in; length, 226in; dry weight, 3,050 lb; mass flow, 100 lb/sec; pressure ratio, 5.5:1; maximum thrust, with afterburner, 7,200 lb, with s.f.c. of 2.2 lb/hr/lb.

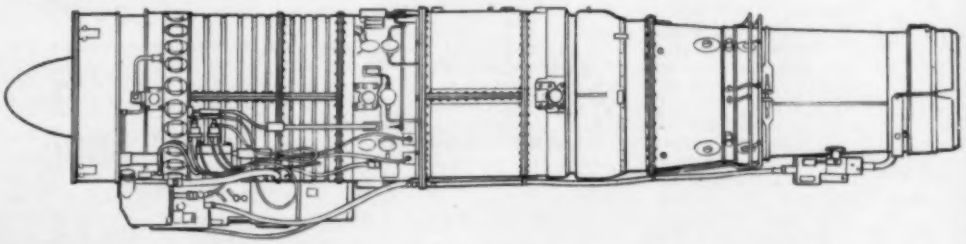
Grand Central Aircraft. *Grand Central Aircraft, Tucson, Arizona.* Better known as the company responsible for extensive modifications to every B-47 and other aircraft, Grand Central are in production with solid-fuel rocket motors. One of these is used in the Bendix Loki surface/air weapon.

Jacobs. *The Jacobs Aircraft Engine Co., Pottstown, Pennsylvania.* Makers of radial air-cooled aero engines since 1929, Jacobs are now concentrating upon three models of the same basic engine, described below. The company made a large proportion of the engines for war-time Canadian Ansons, and their present output comprises precision components and sub-assemblies for military turbojets and aircraft, under sub-contract. They have twelve modern test cells and other facilities for testing air- or liquid-cooled engines.

R-755. Progressively developed over many years, this seven-cylinder radial is in small series production for fixed-wing aircraft: the R-755A develops 300 h.p. for a weight of 505 lb; the B-series has a lower rating of 275 h.p.; and the E-series is generally stronger, has a reduction gear, and a rated power of 350 h.p. The drawing shows the vertical-crankshaft engine being developed for the Jacobs 104 helicopter; this variant of the R-755E has an integral reduction gear with a concentric rotor drive.

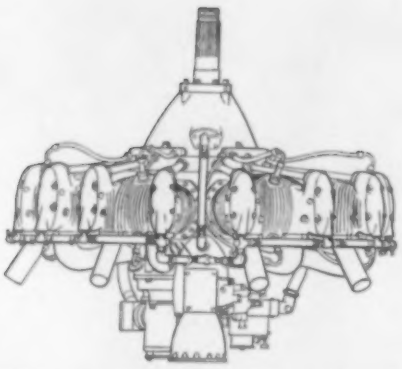


General Electric J47-GE-23 turbojet (PM-25 and ST-25 are similar). Twelve-stage compressor, eight combustion chambers and single-stage turbine. Diameter, 39.5in; length, 144in; dry weight, 2,650 lb; mass flow, 100 lb/sec; pressure ratio, 5.5:1; maximum thrust, 5,800 lb (6,500 lb with water injection) at 7,950 r.p.m. with s.f.c. of 0.98 lb/hr/lb.

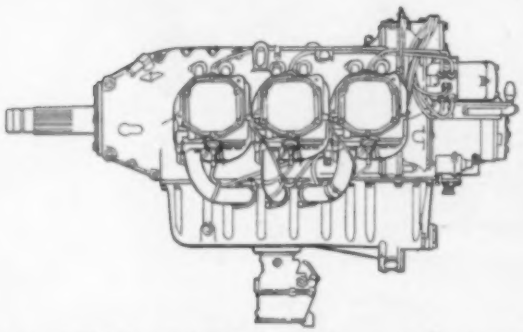


General Electric J73-GE-5 turbojet with afterburner. Twelve-stage compressor, cannular combustion chamber with 10 interconnected flame tubes, and two-stage turbine. Diameter, 39.5in; length, as shown, 200in; mass flow, about 155 lb/sec; pressure ratio, about 7.5:1; maximum thrust, 12,500 lb with afterburner (basic engine is rated at 9,500 lb thrust at 8,000 r.p.m with s.f.c. of 0.90 lb/hr/lb).

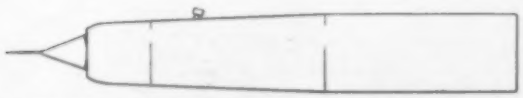
Lockheed. *Lockheed Aircraft Corpn., Burbank, California.* The corporation's new Missile Division apparently intends to develop power units. A number of 20ft-span free-flight test vehicles has been flown, generally with ramjet power. Rockets are also being studied.



Jacobs R-755-HE seven-cylinder, air-cooled radial, unsupercharged and geared to concentric helicopter drive; in the Jacobs 104 helicopter, the engine will have the crankshaft vertical and the engine and transmission will be integral. Bore, 5.25in; stroke, 5in; swept volume, 757 cu in (12.41 litres); diameter, 44in; height, 63.2in; dry weight, 760 lb (standard engine); maximum power, 370 h.p. at 2,650 r.p.m. Not allowing for power taken by cooling fan.



Lycoming O-435-A flat-six, air-cooled piston engine, ungeared and unsupercharged. Bore, 4.875in; stroke, 3.875in; swept volume, 434 cu in (7.3 litres); width, 33.1in; height, 29.6in; length, 38.1in; dry weight, 392 lb; maximum power, 190 h.p. at 2,550 r.p.m. (The geared version gives 260 h.p. at 3,400 r.p.m.)



Marquardt supersonic ramjet. This drawing shows the configuration of the supersonic engines now being made by Marquardt, typical figures for an advanced engine being: diameter, 30in; weight, 1,260 lb; mass flow at under 10,000 ft, about 900 lb/sec; maximum thrust, about 60,000 lb.

Aero Engines 1954 . . .

Lycoming. *The Lycoming-Spencer Division of the Avco Manufacturing Corpn., 420 Lexington Avenue, New York City.* Although the first Lycoming aero engine was a radial, the design of which was begun in 1928, post-war output has, until recently, been entirely of four-, six- and eight-cylinder horizontally opposed engines. The largest Lycoming engine is the R1820 (referred to below), of basic Wright design.

Opposed Engines. The C-235 and 0-290 flat-four engines are both ungeared, unsupercharged engines, giving 115 and 140 h.p.; a new O-320, of 150 h.p. and lower r.p.m. and b.m.e.p., has been developed from the O-290, with ¼in greater bore. The O-435 flat-six is widely used, giving 260 h.p. geared and unblown, and 300 h.p. with a supercharger. A special version of this engine powers the Kaman HTK helicopter, giving 245 h.p. at lower r.p.m. The eight-cylinder O-580 gives 375 h.p. geared and supercharged; for Doman helicopters a special version has been developed running on 100/130 grade fuel, and giving 400 h.p. at 5.8 lb boost for a weight of 597 lb.

R1820. The ultimate version of the classic Wright Cyclone is the range of engines now being developed jointly by Wright and Lycoming, and made by the Bridgeport-Lycoming Division of Avco. These nine-cylinder radials correspond closely to the "E" series of Cyclones, and give up to 1,525 h.p. on 115/145 grade fuel. The R1820-103 is the power unit of the Piasecki H-21 Work-Horse helicopter; the latest has rocker-box drainage permitting pressure-lubrication, and is mounted at a crankshaft angle of 34 deg. A single, dual magneto is fitted, and a cooling fan; it is in production for a secret U.S.N. helicopter.

Marquardt. *Marquardt Aircraft Co., Van Nuys, California.* It was as late as 1944 that Roy E. Marquardt, then only 26 years of age, was enabled to found a company, initially to develop ramjets. Marquardt are possibly several years ahead of any other firm in the world in the ramjet field, and have an annual turnover of many millions of dollars. The company has a valuable test facility in which large ramjets can be "flown" at Mach 3 with any desired air temperature, pressure and angle of attack. This establishment is much in demand for testing missiles developed by other companies.

Another branch of the company's products concerns accessory-drive units driven by ram-air or hydrogen peroxide turbines.

A large number of complete guided-weapon auxiliary-power systems has been developed for both ramjet- and rocket-powered weapons.

Subsonic Ramjets. The first Marquardt contract was for a 20in-diameter ramjet, developing about 2,500 h.p. at full speed of about Mach 0.8. Two were fitted to the wing tips of an F-80 which became the first piloted ramjet aircraft. From 1946 onwards the company delivered large numbers of production engines of 20, 30 and 48in diameter, for piloted aircraft, targets, drones and helicopters.

Supersonic Ramjets. Security veils Marquardt work in this field, but a large number of very advanced engines has been developed. The inactive Grumman Rigel had an integral ramjet; other applications include Lockheed X-7 engine-test vehicles and the Martin Oriole Mach 3 air/air weapon, the latter being a large missile with range too great for a rocket.

McCulloch. *McCulloch Motors Corpn., Los Angeles* 45, *California.* Since 1943 this company has been a major supplier of horizontally-opposed two-stroke engines for drones and targets. A typical example is the 4318A four-cylinder unit, running on 115/145 grade fuel mixed with lubricating oil. This mixture is admitted through rotary valves on the four-throw crankshaft and then passes into the light-alloy die-cast cylinders. At 4,100 r.p.m. this neat engine gives no less than 72 h.p. for a complete weight of 76.5 lb; it is, of course, radio-controlled, and has a short life.

McDonnell. *McDonnell Aircraft Corpn., St. Louis* 3, *Missouri.* This large aircraft-firm has completed a propulsion test laboratory at St. Louis. It has two heavily sound-proofed cells for testing turbojets and ramjets for helicopters and guided weapons. A 3,000 h.p. electric motor supplies a small airflow at high pressure or, conversely, a 13½in jet at about Mach 1. McDonnell have already made tip-drive subsonic ramjets.

North American. *North American Aviation, Inc., Los Angeles 45, California.* This huge aircraft company, of enormous wealth, is likely to become the greatest manufacturer of very large rockets in the world. With Air Research and Development Command assistance, the world's biggest rocket-test establishment has been built near Santa Susana, and other units have been sled-tested at Edwards A.F.B., California.

One proven engine is a "loxygen"/alcohol unit of 50,000 lb thrust which is being used in four- and two-barrel applications. Another has been described as giving V-2 performance but one-third smaller than the German rocket. The company's chairman has spoken of rocket-fuel pumps requiring a 1,700 h.p. drive. N.A.A. rockets are fitted to the Chrysler Redstone, General Electric Hermes 300-mile bombardment weapon, various high-altitude ground/air weapons, and North American's own atomic-warhead Navaho intercontinental weapon.

N.A.A. are also major Atomic Energy Commission contractors for the development of power units using sodium-cooled reactors with graphite moderators.

Phillips Petroleum. *Phillips Petroleum Co.* are the contractor/operator of the 18,000-acre U.S.A.F. "Blue Bonnet" plant in Texas, where they are developing petroleum-derived rocket fuels, with the emphasis on solid propellants.

Pratt and Whitney. *Pratt and Whitney Aircraft Division of United Aircraft Corpn., East Hartford* 8, *Connecticut.* Since 1925, Pratt and Whitney has been the world's largest manufacturer of aero engines. The company's production piston engines have all been air-cooled radials, the first design—the 1,340 cu in Wasp—still being built. Gas-turbine development was begun in 1945, with the T34 unit. In 1946, some production experience was obtained by making 130 Westinghouse J30 turbojets for the Navy, and an agreement was concluded with Rolls-Royce in 1947 whereby Pratt and Whitney received American manufacturing and sales rights for Rolls-Royce centrifugal turbojets. Production is now concentrated on the company's own turbojet, the J57.

Gas-turbine work has required a research investment four times as great as the company possessed in 1945. One such establishment is illustrated on p. 433. Total manufacturing area exceeds 4m sq ft, and employment exceeds 35,000. About half the company's production is let out to some 5,280 sub-contractors. Very extensive research is being carried out, including ramjet development and basic nuclear propulsion study, the latter in association with Boeing.

Early Piston Engines. The R-985 Wasp Junior, of 450 h.p., is very widely used in many countries in fixed- and rotary-wing aircraft; it is no longer in production. The R-1340 Wasp, of 600 h.p., is in production by Canadian Pratt and Whitney. The world's most widely-used engine, the R-1830 Twin Wasp, is no longer being built, and spares are usually the result of cannibalizing. The R-2000 Twin Wasp, specially produced in 1937 for the DC-4, is still in production at a rating of 1,450 h.p. Small numbers of R-2180 Twin Wasps are being made; developed solely for the Saab Scandia, these engines resemble the R-2000 but have a stroke of 6in (¼in more) and give 1,800 h.p.

R-2800. The Double Wasp provided more aggregate horsepower than any other engine at the end of World War 2, and has since been built for such machines as the C-119, DC-6, CV-240/340 and F4U. An 18-cylinder engine, many sub-types are in use, with one- or two-speed superchargers and using different fuel grades; nearly all have water injection. A recent range, now in large-scale production, is intended for helicopters, and has a 1,900 h.p. continuous rating. The military R-2800 is still built by the Nash-Kelvinator Corpn., at Kenosha and Milwaukee, Wisconsin.

R-4360. The Wasp Major was designed early in World War 2, and is the largest piston engine ever to go into production. The cylinders are similar to those of the Double Wasp, and the four rows are staggered so that, with suitable baffles, adequate cooling is obtained by the rear rows; hence the appellation "corncob." Various types are in use, the majority having a single-speed gear-driven supercharger and one or two remote turbo-superchargers. The commercial Wasp Majors have four-barrel injection carburettors, but the military engine shown (used in the B-36H) has direct fuel injection, and runs on 115/145 fuel.

Military R-4360 production is at present tapering off at the Ford plant at Chicago, in favour of the J57.

J42. Basically an "Americanized" Rolls-Royce Nene 2, the J42 was made in numbers for the U.S. Navy, but is now out of production. Compared with most British Nenes, the J42 has a magnesium compressor case, water injection, and runs at lower r.p.m. It is used in the F9F-2 Panther.

J48. The J48 was a parallel development of the Nene in conjunction with Rolls-Royce, the British engine being the Tay. Dimensionally interchangeable with the J42, the J48 has a greater mass-flow, and gives much greater thrust in spite of lower r.p.m. The engine shown, used in the F-94C Starfire, has a large afterburner of Pratt and Whitney design, and costs about £22,000. The basic engine, used in the F9F-5 Panther and F9F-6 Cougar, gives between 6,250 and 7,000 lb dry, or about 1,000 lb more with water injection. Production will cease this summer.

J57. Most important engine in America, the J57 is the first gas-turbine of Pratt and Whitney design to go into production. From the start, an exceptionally high pressure-ratio was sought, and the resulting engine is a two-spool unit, made entirely of steel, and suitable for high-speed flight in arduous conditions. A unique cannular combustion system has been evolved, with eight individual annular flame tubes spaced around the engine, each tube having six burners. Combustion is good even at 50,000ft, but the engine smokes at full throttle. Three turbine stages are used, the rear two driving the low-pressure compressor.

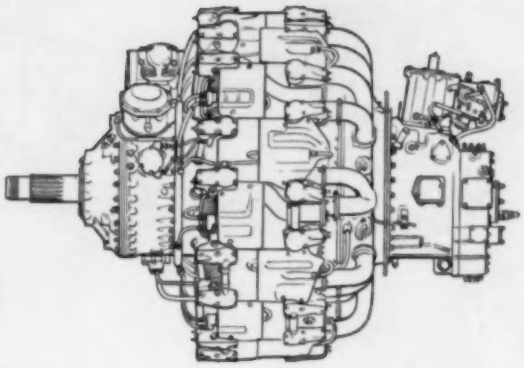
For bombers and transports the J57 is podded, with a stainless-steel duct bleeding off air for cabin and auxiliary supplies. For fighters, a very good Pratt and Whitney afterburner has been developed, with excellent properties up to high altitude (in this, the very high gas-pressure throughout the engine is an advantage) and providing 50 per cent augmentation to a total of 15,000 lb thrust.

The J57-P-3, illustrated, powers the B-52A; other applications are the F-100, 101 and 102, A3D, F4D and F8U, and the civil JT3L is the basis of most American airliner projects, including the Boeing 707. The company's main factory delivered 150 J57s during the first quarter of 1953 and production is probably well over one hundred a month. A second source is now the Ford Chicago factory.

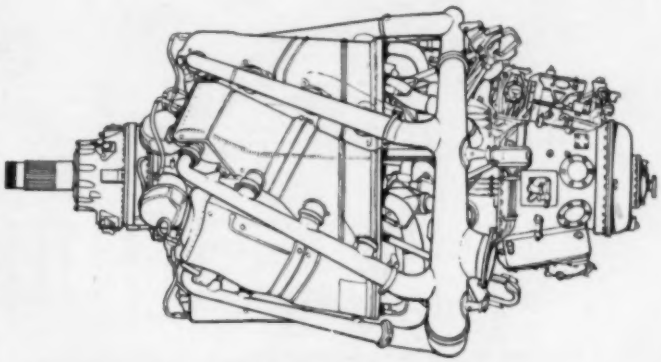
J75. A logical advance on the J57, the J75 is likewise an all-steel, split-compressor turbojet, with a mass flow of some 230 lb/sec. The design thrust is of the order of 15,000 lb (21,000 lb with reheat); much bench and component running has been completed, and the engine is being reckoned with by airframe manufacturers.

T34. Steadily developed from November 1945 onwards, this is a long, slim, all-steel, single-shaft turboprop, which can be considered the only fully-developed engine in its class in the world. The compressor works at medium pressure ratio, and has blow-off valves for starting. The slim 11:1 reduction gear is flexibly attached to the front of the compressor, and the steel compressor casing carries the annular combustion chamber at the rear.

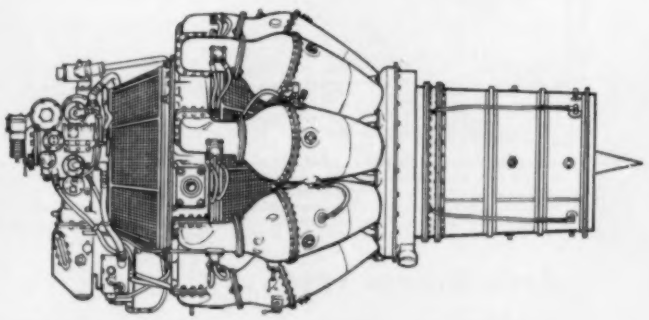
The whole power unit is mounted on four large rubber "Dynafocal" mounts spaced around the engine's waist. Single-lever control is provided by a hydro-mechanical system linking r.p.m., airscrew pitch and fuel feed. The T34 is de-iced by compressor-bleed air, and the usual starter is an AiResearch air-turbine motor. Most T34s have a sliding bullet inside the tailcone, to vary the



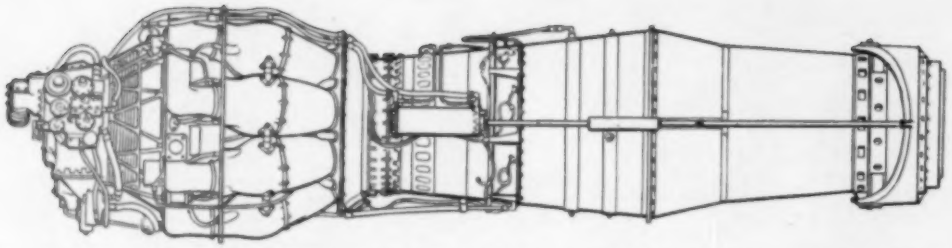
Pratt and Whitney Double Wasp R-2800 CB16 eighteen-cylinder, two-row, air-cooled radial, geared and fitted with two-speed supercharger, three-barrel injection carburettor and water injection. Bore, 5.75in; stroke, 6in; swept volume, 2,804 cu in (45.9 litres); diameter, 52.8in; length, 81.4in; dry weight, 2,390 lb; maximum power, 2,400 h.p. at 2,800 r.p.m. (wet) with 14.3 lb boost.



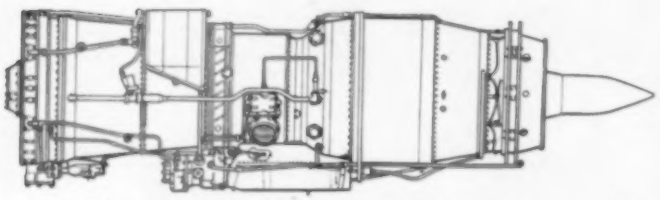
Pratt and Whitney Wasp Major R-4360-53 twenty-eight cylinder, poppet-valve, air-cooled, four-row radial, fitted with a single-stage supercharger and used in the B-36H with two turbo-superchargers and aftercoolers; fitted with geared drive, direct fuel injection and water-injection system. Bore, 5.75in; stroke, 6in; swept volume, 4,363 cu in (71.5 litres); diameter, 55in; length as shown, 109in; dry weight, 3,730 lb; maximum power, 3,800 h.p. at 2,800 r.p.m. (Note: Drawing shows cooling baffles and ceramic-lined exhaust system.)



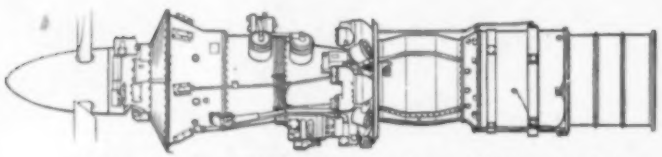
Pratt and Whitney Turbo-Wasp J42-P-6 turbojet. Single double-sided centrifugal compressor, nine combustion chambers and single-stage turbine. Diameter, 49.5in; length, 103.2in; dry weight, 1,729 lb; mass flow, 88 lb/sec; pressure ratio, 4.3:1; maximum thrust, 5,750 lb at 12,300 r.p.m. with water injection.



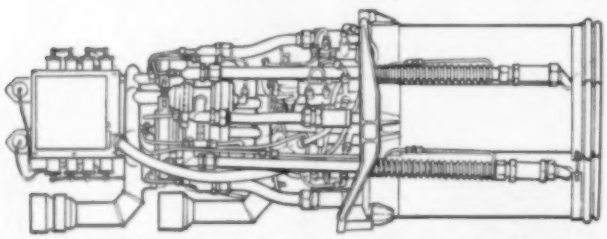
Pratt and Whitney Turbo-Wasp J48-P-3 turbojet with afterburner. Single double-sided centrifugal compressor, nine combustion chambers, single stage turbine, afterburner with two pneumatically-actuated eyelids and automatic control. Diameter, 50in; length, 226in; dry weight, 2,800 lb; mass flow, 115 lb/sec; pressure ratio, 4:1; maximum thrust, 8,500-9,000 lb at 11,000 r.p.m. with re-heat for s.f.c. of 2.5 lb/hr/lb (basic engine cleared for 7,000 lb with water injection).



Pratt and Whitney J57-P-3 two-spool turbojet. Nine-stage low-pressure compressor and seven-stage high-pressure compressor, driven by single and two-stage turbines respectively, and eight "annular-type" combustion chambers each with six burners, mounted in single annular combustion space. Diameter, 41in; length, 141in; dry weight, 4,150 lb; mass flow, 195 lb/sec; pressure ratio, 12.5: 1; maximum thrust, 10,000 lb dry with s.f.c. of 0.76 lb/hr/lb.



Pratt and Whitney T34-P-3 single-shaft turboprop. Thirteen-stage axial compressor, annular combustion chamber with six flame tubes, and three-stage turbine. Diameter, 34in; length, 157.4in; dry weight, 2,564 lb; mass flow, about 77 lb/sec; pressure ratio, 6.7: 1; maximum power, 5,300 s.h.p. plus 1,040 lb thrust at 11,000 r.p.m., giving total e.s.h.p. of 5,700, with s.f.c. of 0.62 lb/hr/e.s.h.p.



Reaction Motors A6000C4-2 bi-fuel rocket running on liquid oxygen and ethyl alcohol. Four combustion chambers, regeneratively-cooled, each with its own fuel supply and control system, fuel being delivered by two turbo-pumps driven by the main fuel supply. Diameter 19in; length, 56in; dry weight, 210 lb; specific impulse, 192 sec; jet velocity, 6,182 ft/sec; maximum thrust (four barrels), 6,000 lb at any altitude, with s.f.c. of 18.75 lb/hr/lb.

Aero Engines 1954 . . .

tailpipe area, and an airscrew brake and a torquemeter are standard fittings.

Most pre-production work on the engine was done by Allis-Chalmers, but the T34 is now in full production by Pratt and Whitney for U.S.A.F. and U.S. Navy transports. The civil PT2F-1 awaits applications.

New Turboprops. At present, Pratt and Whitney hold a Navy development contract for the T52, a single-shaft engine now running at 8,500 e.h.p. The T48 is another unit in about the same power category, while a much larger two-spool engine is being rapidly developed, using J57 parts wherever possible. To give 15,000 e.h.p., this engine is scheduled to power the huge Douglas XC-132.

R.M.I. *Reaction Motors, Inc., Rockaway, New Jersey.* This company was a direct outgrowth of the pre-war work of four members of the American Rocket Society, and was formed in December 1941. By that time the foundations had been laid for the development of a variety of rockets, most of the effort being on bi-fuel liquid rockets with regenerative cooling. Many of the early units ran on liquid oxygen/petrol or nitric acid/aniline, but the propellants selected for major applications were "loxygen" and alcohol. The most famous of all these units is shown alongside; of 1946 vintage, it powered the Bell X-1 and Douglas D-558-2 research aircraft, and was controlled by switching on or off individual barrels. Later versions of this unit are employed in the Bell X-1A and B, with a turbo-pump, as opposed to gas pressure, feeding the fuel.

The same fuels are used in the four-cylinder, 8,000 lb-thrust motor of the Convair MX-774 vehicle, and the 20,000 lb-thrust single-chamber motor of the Martin Viking sounding rocket, which holds the height record for single-step vehicles at 136 miles. The XLR-10 is another single-chamber unit of 20,500 lb thrust, reportedly for multiple installation in large missiles. Another big motor is being developed for the Bell X-2 research aircraft. R.M.I. are expanding rapidly, and a new £1.5m Navy-sponsored building is now nearing completion.

Ryan. *The Ryan Aeronautical Co., San Diego 12, California.* Ryan hold a £400,000 Army contract for Aerojet liquid-fuel rockets to power Corporal E, a Firestone surface/surface weapon.

Solar. *Solar Aircraft Co., San Diego, California.* This company, also referred to on p. 442, is in volume production with several types of gas-turbine-driven auxiliary power unit, the best-known being the Air Force MA-1 of 32 h.p. and the Navy 55 h.p. engine. In 1950 the T-400 shaft-drive engine was prepared for helicopter propulsion, and this reverse-flow engine has since been followed by the Jupiter, a compact free-turbine unit of over 400 h.p. principally for rotary-wing applications.

Westinghouse. *Aviation Gas Turbine Division, Westinghouse Electric Corpn., Lester Branch P.O., Philadelphia 13, Pennsylvania.* This huge company, with interests in many fields, began gas-turbine development at the instance of the U.S. Navy in 1941. From the outset, they adopted the axial compressor and annular combustion chamber and have produced a series of long and thin turbojets which owe little to any other company's work. In particular, credit is due to Westinghouse for the "step-wall" combustor, which has since been widely adopted.

The first engine ran in March 1943, and initial developments gave from 500 to 2,000 lb thrust. The J34 is the most successful engine, of 1945 design, but both the J40 and J46 have had to be largely abandoned owing to fundamental and detail defects. The failure of these engines has been a bitter blow to Westinghouse and to the Navy, who paid for their development. An agreement with Rolls-Royce was signed last year providing for an interchange of men and information, which has proved beneficial to the stubborn Westinghouse engines. Last December the New York engineers Sanderson and Porter were also engaged as jet consultants. The company are reported to be trying to interest the Navy in "a large turbojet with Rolls-Royce principles."

J34. Power unit of the F3D and F2H twin-engined carrier-based fighters, the J34 has been built from 1947, and is only now passing out of production. Around the intake is wound an oil-cooler ring made from rectangular-section tube; the annular chamber has 24 inner and 36 outer burners with flame igniters; and short and long types of afterburner have been developed, raising the thrust to 4,200 lb.

J40. This massive engine exists in several forms, the example shown being the original F4D Skyray engine, with a long afterburner, twin oval intakes and a front wheelcase. In other forms the J40 has a single intake. The flexible piping seen in the drawing conveys fuel at 600 lb/sq in to 16 Duplex burners; the afterburner is fitted with eyelid shutters positioned by some 14ft of push/pull rod leading, *via* a yoke-piece, to an electric actuator mounted under the basic engine. The engine has compressor-bleed de-icing, and is in limited production for the first 250 F3H Demons (later Demons will have the J57).

J46. Rather larger than the J34, the J46 was scheduled to power the F2Y Sea Dart and F7U and A2U Cutlass. Owing to

WALKER'S products keep abreast with Aircraft developments

some outstanding examples . . .

- ***"UNIVOIL"*** — A highly specialised rubber compound resistant to Mineral and *Synthetic* Oils without undue swelling or shrinkage.
  This material complies with:
  DTD 552 Grade B.
  DTD 458A Grade B.
  DTD 560 Grade B. Qualities P & Q.
- ***"METAFLEX"*** — Spiral wound stainless steel and asbestos gaskets for hot air anti-icing and heating flanges and all conditions of extreme temperatures up to 800°C.
- ***"TWILSTELE"*** — A sheet gasketing material—Twill woven stainless steel and asbestos —for temperatures up to 800°C.
- ***"FLUOLION"*** (PTFE) — Walker's version of Mouldings, Tape, and Envelope type joints, etc., made from Fluon.
- ***'O' SEALS*** — All types of Synthetic Rubber Compounds.
- ***"SILICONE"*** — Mouldings in SILICONE Rubber and SILICONE Impregnated Fabric.

Technical Enquiries Invited

Send your Packing and Jointing problems to:—

JAMES WALKER & CO. LTD.

"LION" WORKS - WOKING - SURREY - ENGLAND

Telephone: Woking 2432 (8 lines) Telegrams: "Lioncello, Woking, Telex" Depots throughout the World

Tib. 254

Call up the (sea) little horses!

When the Saucy Maggie B., that new greyhound of the ocean, was lying half-completed in a small Scotch burn called the Clyde the Chairman of the Company had a brainwave. Call up the Desoutter Little Horses ! he cried. Turn them loose to get on with the fitting and we'll soon be all at sea. And before he had time to shiver his timbers a crew of Little Sea Horses was swarming up the side, there was a great noise of drilling and screwing, the Saucy Maggie put to sea, and the Blue Riband of the Gigantic Ocean was dangling round the Chairman's neck.

Desoutter power tools *Put you all at sea!*

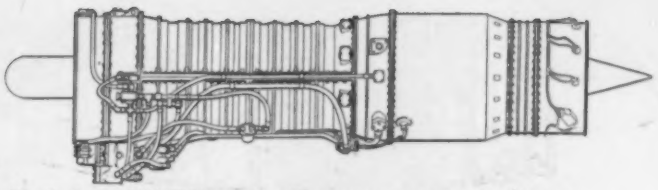
Desoutter Bros., Ltd., The Hyde, Hendon, London, N.W.9. Telephone: Colindale 6346 (five lines) Telegrams: Despnuco, Hyde, London

CRC353

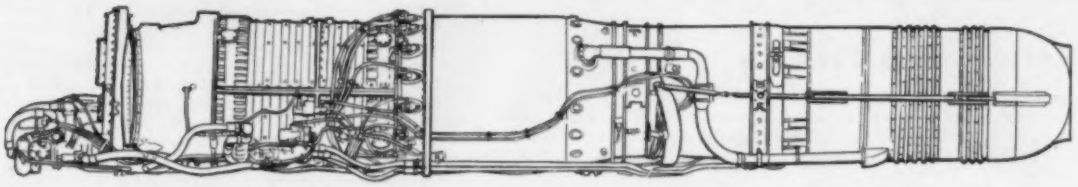
Aero Engines 1954 . . .

combustion instability and poor control, particularly at altitude, the engine is by no means fully developed. The Cutlass engine has an afterburner, as illustrated, and limited production is proceeding at the company's main turbojet plant at Kansas City.

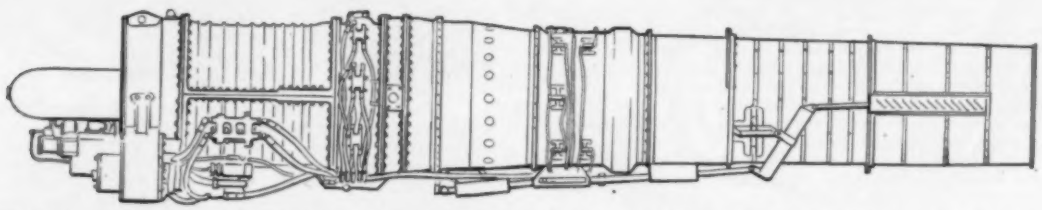
Wright. *Wright Aeronautical Division, Curtiss-Wright Corpn., Wood-Ridge, New Jersey.* Longest-established of all the American engine companies, Wright have had various types of Cyclone piston engine in production since 1930. The company's first venture into gas-turbines was the T35 single-shaft



Westinghouse J34-WE-36 turbojet. Eleven-stage compressor, annular combustion chamber with 24 + 36 burners, and two-stage turbine. Diameter, 24in; length, 120in; dry weight, 1,233 lb; mass flow, 55 lb/sec; pressure ratio, 3.8:1; maximum thrust, 3,400 lb at 12,500 r.p.m. with s.f.c. of 1.01 lb/hr/lb.



Westinghouse J40-WE-8 turbojet with afterburner. Ten-stage compressor, annular combustion chamber with sixteen burners, two-stage turbine, and large afterburner fitted with sideways-opening eyelids both actuated from single electric jack. Diameter, 40in; length, 300in; dry weight, 3,500 lb; pressure ratio, 5.2:1; maximum thrust, 10,500 lb at 7,600 r.p.m. with s.f.c. of about 2.2 lb/hr/lb; basic engine gives 7,500 lb for s.f.c. of 0.935 lb/hr/lb. (Note: in this fighter engine, the accessories are mounted between bifurcated intakes.)



Westinghouse J46-WE-8 turbojet with afterburner. Eleven-stage compressor, annular combustion chamber with multiple burners, two-stage turbine and afterburner with twin eyelids positioned by single jack. Diameter, 34in; length, 198in; dry weight, 2,100 lb; mass flow, about 78 lb/sec; pressure ratio, about 6:1; maximum thrust, 6,000 lb with re-heat, or about 4,800 lb basic.

turboprop of 1945 design, which was cancelled after 17 had been delivered at a cost of £9.9m. Wright then obtained licences to build and develop most modern Armstrong Siddeley engines, the most important being the Sapphire (below). Licences are also held for the development of the Bristol Olympus, and the company are negotiating for the former Navy factory at Romulus, Michigan (left vacant by the revised programme for the J40 engine) for the production of the Olympus-derived J67.

About 25,000 employees are at present making piston engines, J65s, ramjets, and are conducting tests on glass-plastic blading and other developments. Very large turboprops are not far off, and a "throttleable" liquid-fuel rocket is being perfected by the Curtiss-Wright Propeller division; this engine, the XLR-25, gives 12,000 lb thrust, and was intended for the Bell X-2. The company's order-backlog exceeds £350m.

R-1300. This neat seven-cylinder engine is almost entirely a post-war development. Large numbers have been built, principally for the North American T-28A trainer, and the engine gives 800 h.p. at 2,600 r.p.m., geared and supercharged. When Wright farmed out all piston engine work to other firms (with the exception of the Turbo-Compound) responsibility for the R-1300 passed to the Detroit Engine division of Kaiser-Frazer. The latter company are now mass-producing the R-1300-3 for the various service versions of the S-55 helicopter. The R-1300-3 has a special arrangement of lubrication to enable it to be used at 39 deg crankshaft angle. Drive is direct. It is possible that this engine will power some production Westland Whirlwinds.

R-1820. As stated in the section dealing with Lycoming, all responsibility for the R-1820 (the direct descendant of the original Cyclone) is vested in the Bridgeport-Lycoming division of Avco.

R-2600. Mass-produced in World War 2, this 14-cylinder, two-row engine is no longer in production, although it is widely used in such "corporate" aircraft as the Mitchell.

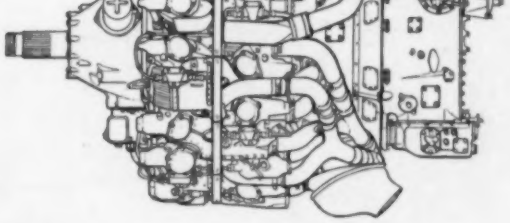
R-3350. Originally known as the Duplex Cyclone, this massive 18-cylinder radial powers the B-29, Skyraider, Constellation and other aircraft. Several variations are in military and commercial use, with fuel injection either into the eye of the supercharger or direct into the cylinders. Water injection and high- or low-tension ignition are other variables. After some 25m flight hours, the R-3350 is well developed, typical figures being the scheduled overhaul life of 1,900 hr for some airline engines and the allotted 600 hr invariably reached by the WB-29 engines of the Air Weather Service. All R-3350 work is the responsibility of the Chevrolet aviation engine division of General Motors, who build the engine at their Tonawanda, New York State, factory.

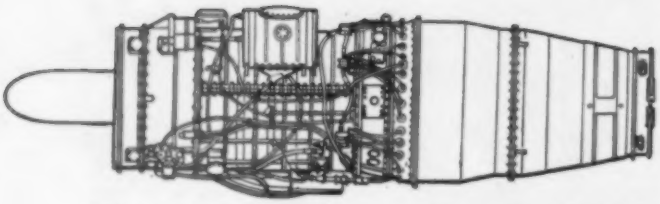
Turbo-Compound. After much war-time research, Wright evolved a method of compounding the basic R-3350 engine, by the addition of a "power-recovery" section just behind the rear row of cylinders. Three small, single-stage, blow-down turbines are fitted on radial shafts spaced around the engine at 120 deg intervals. These turbines are spun by the exhaust gas whenever the engine is running and they are connected, *via* fluid couplings, to the crankshaft, to which they feed up to 600 h.p.

Compared with earlier R-3350s, the Turbo-Compound is still further refined and more strongly made; it is a highly competitive military and commercial engine and is seeing wide service in the P2V, C-119H, P5M, DC-7 and Super Constellation.

At present cleared for 600 hr, it has suffered some trouble, such as nozzle-box cracking and cooling-cap failure. A year ago,

Wright Turbo-Compound R-3350-30WA eighteen-cylinder, two-row radial, air-cooled piston engine, geared and fitted with two-speed geared supercharger, pressure-type carburetter and water-injection system, and having a power-recovery section of three exhaust-driven turbines geared to the crankshaft through fluid couplings. Bore, 6.125in; stroke, 6.3125in; swept volume, 3,347 cu in (54.9 litres); diameter, 56.6in; length, 91.8in; dry weight, 3,443 lb; maximum power, 3,500 h.p. at 2,900 r.p.m. with 13.5 lb boost with water injection.





Wright J65-W-3 turbojet. Thirteen-stage compressor, annular combustion chamber with 36 burners and two-stage turbine. Fuel/air starter and shielded high-energy ignition. Diameter, 37.5in; length, 146in; dry weight, 2,600 lb; pressure ratio, about 7:1; maximum thrust, 7,220 lb at 8,200 r.p.m. with s.f.c. of 0.91 lb/hr/lb.

Aero Engines 1954 . . .

various modifications were made to satisfy the C.A.A., including the addition of a 2in-wide ring of ½in armour around each turbine, better cooling and detail changes giving an increased differential between wheel speed (about 19,000 r.p.m.) and disc-failure speed. The Turbo-Compound costs about £25,000. Production at Chevrolet's Tonawanda plant supplements that from Wright's own Turbo-Compound factory, the latter being organized on a completely automatic assembly-line basis.

J65. For a sum reported as £139,930, Wright obtained a licence to develop and manufacture the Armstrong Siddeley Sapphire turbojet. The eventual J65 is fairly far removed from the British engine; Wright switched to steel compressor-blading in parallel with Armstrong Siddeley, but re-designed the centre-bearing support—which in the original engine supplied to them was profiled from a solid light-alloy forging—as a precision-welded assembly in spheroidal-graphite cast-iron sheet. Metal-braided flexible pipe replaces much of the rigid pipe of the British engine, and other changes include a re-rating of the first engines to run at no more than 8,200 r.p.m.

The J65-W-1, 3 and 5 are in volume production for the B-57 and F-84F, the two latter engines having a 340 h.p. Eclipse fuel/air starter. The J65-W-2 is being turned out for the FJ-3 and 4, while Buick motor division of General Motors are making the J65-B-3, with fuel/air starter, at Flint, Michigan. Buick made the engines for the first 100 B-57 Canberras, and are reported to pay Armstrong Siddeley £22 royalty on each Sapphire.

J67. Bristol's engine division supplied more than one Olympus to Wright, and these engines have since been intensively studied, most of the flying being done with an Olympus slung beneath a B-29. The object is the development of a two-spool turbojet with a greater mass flow than the present British engine, and with a thrust of 15,000 lb, or 25,000 lb with afterburner. This performance will take some years to realize; known as the J67, the engine may power later F-100s, F-102s and the YF-103.

T47. Component testing is under way in the development of this turboprop development of the Olympus. With an 8 : 1 reduction gear driven off the front compressor, the mass flow is to be about 165 lb/sec, the total e.s.h.p. about 16,000 (making allowance for 4,700 lb thrust) and the weight 5,900 lb.

T49. Wright's single-shaft turboprop version of the Sapphire has been doing bench running for some 18 months, and flight trials in a B-47 are overdue. Otherwise known as the TP-51, this engine is designed to give 9,000 s.h.p. and 3,450 lb thrust at 8,000 r.p.m. at sea level, with an s.f.c. of 0.68. At altitude, the consumption drops to the competitive value of 0.45 at 35,000ft. The gas-generator section of this engine is considered highly developed, but airscrew and control problems are still being met.

The weight is at present some 4,250 lb, including major accessories; this is some 1,600 lb more than the Sapphire turbojet and indicates the amount of gearbox and extra turbine stages necessary.

FRANCE

Dassault. *Avions Marcel Dassault, 46 Avenue Kléber, Paris 16e.* Probably the most prosperous and productive of all French aircraft companies, Dassault hold a licence to manufacture the Armstrong Siddeley Viper turbojet. They are rapidly completing tooling for an engine known as the M.D.30, which is almost indistinguishable from the "long-life" Viper ASV.5; production should begin this summer, reportedly for a twin-engined, delta intercepter.

Hispano-Suiza. *Société d'Exploitation des Matériels Hispano-Suiza, Rue du Capitaine Guynemer, Bois Colombes (Seine).* Renowned for their vee-twelve liquid-cooled engines, which have served as the prototypes of most Russian engines of this type, Hispano-Suiza have based most of their post-war output on centrifugal turbojets of basic Rolls-Royce design. The original Nene manufacturing licence was signed in 1946 and, since that year, the power potential of the Nene has been stretched to the utmost.

From 1949 the company developed an efficient system of afterburning, with re-heat fuel supplied by a pump driven by a compressor-bleed air turbine. At the same time, a completely automatic control system was evolved, and the whole system was subjected to exhaustive trials on a Nene mounted above the fuselage of a Languedoc. The other work of the company consists of the production of turbo-pumps, spares for Pratt and Whitney R-2000-13 engines for Air France DC-4s, and general overhaul of Merlins of the French Navy's Lancasters.

Piston Engines. The only unit remaining in production is the 12-Z-17, a direct-injection 36-litre engine giving some 1,300 h.p., of which some hundreds have been made since the war. Nearly all have gone to Spain (for Me109s) and Yugoslavia. Provision is made for a *moteur canon.*

Nene. Production of the Nene meant the establishment of a complete new industry in France, both as regards materials and labour. Actual production of the Nene began in 1948, and has continued without interruption; total French production is now approximately 1,000 engines. The first production version was the Nene 102, weighing 1,720 lb and giving 5,000 lb thrust at 12,300 r.p.m. (i.e., as British).

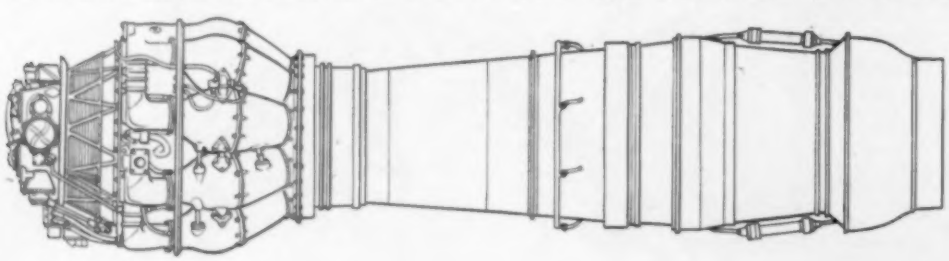
Development of this engine has roughly paralleled Rolls-Royce work, but there are differences in flame-tubes, turbine housing, control accessories and other parts. The Nene 104 and 105, the present engines for Mistrals and Ouragans, make much use of magnesium alloy, cutting the weight to some 1,610 lb. At 12,500 r.p.m. about 5,070 lb thrust (series 104) or 5,180 lb (105) is available. Water injection is not employed. For experimental purposes only, the afterburning Nene 102-B was developed, weighing 2,150 lb and giving 6,800 lb thrust with re-heat. A photograph appears on page 441.

R-300. Stemming from the Nene, this engine is an all-French development, with considerable detail redesign. The entire gas path was revised to permit a greater mass flow, and forced-air cooling was employed for the hollow turbine nozzle vanes. Interchangeable with the Nene, and capable of being made with Nene tooling, the R-300 gave 5,940 lb thrust, but its potential did not merit production in the face of the bigger Tay.

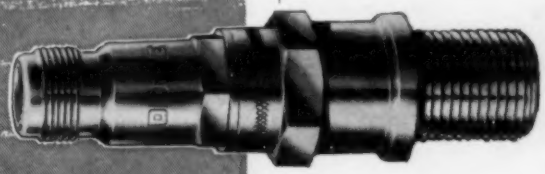
Tay. The licence to build this engine was signed in 1951. After several prototypes and a pre-production run, the Tay 250 went into full production last year; early engines went into the Mystère II, III and IV, and the production Tay 250 is for the "off-shore" Mystère IV-A. Hispano-Suiza have developed the Tay to improve both performance and general durability. The present mass flow is 115 lb/sec at 10,800 r.p.m., giving a thrust of 6,280 lb. The weight is about 2,010 lb.

Verdon. Following Rolls-Royce practice in naming turbine engines after rivers, this all-French development of the Tay is probably the most potent centrifugal turbojet that will be made. Compared with the Tay, the Verdon 450 has a modified compressor, with new curved rotating guide vanes, revised flame-tubes and cans, new turbine blades and disc and improved cooling. An electro-magnetic turbine-temperature control is fitted, and a matched afterburner has been run with the engine, using

Hispano-Suiza R-450 Verdon turbojet with afterburner. Single double-sided centrifugal compressor, nine combustion chambers and single-stage turbine; afterburner with twin eyelids actuated by compressor-bleed jacks and equipped with automatic controls. Diameter, 50in; length, 212in; dry weight, about 2,450 lb; mass flow, about 130 lb/sec; pressure ratio, 4:1; maximum thrust, 9,920 lb at 11,100 r.p.m. with reheat or 7,720 lb basic with s.f.c. of 0.98 lb/hr/lb.



Half-a-Century of service to the aircraft industry by



LODGE

Right from the earliest pioneering days of powered flight, Lodge Plugs have been closely linked with the Industry's amazing progress, culminating today in many of the leading airlines of the world, the R.A.F., the air forces of the Commonwealth and many other countries fitting Lodge sparking plugs and jet igniters.

With Lodge plugs in your car you will also enjoy aircraft engine reliability because the heart of these plugs—exclusive "SINTOX" insulation—will be the same as used in Lodge aircraft plugs.

LODGE PLUGS LTD., RUGBY, ENGLAND

A Chemical Cleaning Process and machine has been developed by Lodge Plugs Limited to supersede the sandblast method.

For full details apply to Service Department (Ae.S), Lodge Plugs Limited, Rugby, England.

The aeroplane The Hawker Hunter. Generally accepted to be the best fighter in the world, this super-sonic aircraft is expected to be in general service with the R.A.F. later this year. Span : 33′ 3″. Length : 45′ 3″. Powered either by a Rolls Royce Avon or Armstrong Siddeley Sapphire

the pilot At 31 years of age, Neville Duke, Chief Test Pilot at Hawkers, is the holder of an impressive and distinguished record, and was recently awarded the O.B.E. During the war he won the D.S.O., D.F.C. and 2 Bars, A.F.C. and Czech. Military Cross. He was credited with 28 confirmed victories. Since then he has contributed his services to the Empire Test Pilots School, High Speed Flight, and The Ministry of Supply's Establishment at Boscombe Down. He has served as C.O. of 615 Squadron, Biggin Hill. Of the Shell and BP Aviation Service he has this to say :— "I have always been provided with prompt and efficient service by Shell and BP."

Shell and BP Aviation Service On distant tarmacs the sight of the unmistakable Shell and BP Refuelling trucks is a reassuring sign to pilots. Here, indeed, is a home-away-from-home. Airmen, whether commercial, Forces or private, know the comfort of one less problem on their hands. Aircraft manufacturers rest in the assurance that their fuelling specifications can and will be met. These immense resources are yours for the using any time — and practically anywhere.

SHELL-MEX AND B.P. LTD., Shell-Mex House, Strand, London, W.C.2.
Distributors in the United Kingdom for Shell and Anglo-Iranian Oil Groups.

Aero Engines 1954 . . .

the Hispano-Suiza control system. Verdons flew in Mystère II and IV-A prototypes during 1952-53, and the engine is this month replacing the Tay as the power plant of the Mystère IV-A, the engine mountings being interchangeable.

Avon. Last summer a licence was signed giving the French company authority to develop and build the Rolls-Royce Avon. Last December the first Mystère IV-B flew with an English Avon RA.7R, and different prototypes are now being fitted with other Derby-made Avons. Plans are being concluded for manufacture of Avons of unspecified types in France for the Mystère IV-BN and XX, SO-4050 Vautour, SE-2410 Caravelle and Hurel Dubois H.D.45.

Leduc. *René Leduc et Fils, Argenteuil, Seine-et-Oise.* For over 20 years René Leduc has been steadily developing pure-ramjet aircraft, of which four full-scale prototypes have been built since the war, with the fifth—and first to be supersonic—nearing completion. Although his work has had to depend on meagre financial support, a very great deal has been accomplished, and satisfactory efficiency, combustion and control have been achieved up to about 60,000ft.

In all the full-scale machines the fuselage itself forms the power-plant, the whole structure being a propulsive duct, with the exception of a small streamlined cockpit mounted concentrically in the intake. The interior of the duct is divided into several concentric diffusers by a system of splitter tubes; each of the latter has an array of fuel injectors around the leading edge—about 500 altogether—the resulting combustion taking place within the annular spaces between the tubes; in the earliest machines, at least, no flameholders were fitted. The Leduc 022, now being built, is designed for Mach 2, and will be a prototype intercepter.

Lutetia. *Moteurs Lutetia, Neuilly-sur-Seine, Seine.* The Lutetia company has concentrated on small two-stroke engines which are unique in design. The principal types—a four-cylinder 90-deg vee of 44 h.p. and a six-cylinder radial of 70 h.p.—have the cylinders cast in pairs, so that the six-cylinder unit appears to have three oval-section cylinders spaced at 120-deg intervals around the crankcase. Air cooling is employed, and a positive-displacement compressor assists scavenging.

Mathis. *Société Mécamat, Gennevilliers, Seine.* Quite large numbers of Mathis flat-four and inverted vee-eight engines are in service in many types of aircraft, but no information is available regarding the company's present position. The engines now in use have maximum powers of 92, 200 and 230 h.p.

Minié. *Victor Minié Aéronautique, 9 Place des Ternes, Paris 17e.* This large light-alloy-casting company has developed a range of small, horizontally-opposed, air-cooled, four-stroke engines, in which the most modern casting techniques have been employed. Three models currently produced are a two-cylinder unit of 35 h.p., and a series of four-cylinder engines of 65 and 90 h.p.

Potez. *Moteurs Henry Potez, 45 Avenue Kléber, Paris 16e.* Air-cooled units of medium power are now in production at the old Lorraine works at Argenteuil, the output largely consisting of 6D engines for military trainers. At present the company has a fully-developed range of four-in-line, six-in-line and vee-eight engines, all inverted and all using the same size of cylinder. The four- and six-cylinder units are available with or without a supercharger, and are ungeared; powers are 220 and 305 h.p. for the supercharged units. The eight-cylinder engine, illustrated, powers the Potez 75 "tank buster" prototype; in this pusher installation a large cooling-fan is fitted between the reduction gear and the airscrew.

Rateau. *Société Rateau, La Courneuve (Seine).* This well-known turbine and air-compressor firm were engaged in aircraft gas-turbine development as early as 1939. Work continued, under obvious difficulties, during German occupation, and was eventually co-ordinated under Government approval in 1946. After making an interesting by-pass engine, M. Anxionnaz and his team developed the engine described below.

SRA-101 Savoie. Bearing in mind its early conception, this turbojet is remarkably sound in design and has a performance fully comparable with that attained by some engines developed more recently by larger firms. Of all-steel construction, the Savoie abounds in unorthodox features, such as the taper of the compressor casing in the reverse of the usual manner; the strange rows of bleed pipes around the same casing (which is, into the bargain, a single-piece steel unit); the abrupt increase in diameter beyond the compressor to a clearly-defined maximum; and the large pipes lying between the flame-tubes, which appear to by-pass compressor air around the combustion chamber. Tailpipe area is variable, there being a sliding inner cone.

Irrespective of its appearance, the Savoie has a fine performance. It has been built in small numbers purely as an experimental venture, but it has not yet flown.

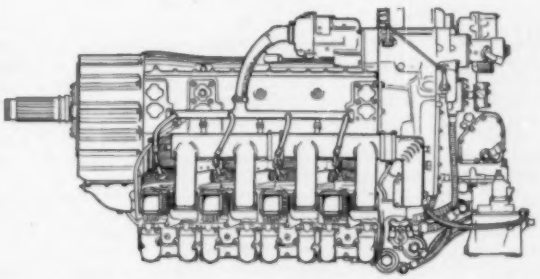
Salmson. *Moteurs Salmson, Billancourt, Seine.* Although this long-established company went into voluntary liquidation in 1951, a spares-and-service organization still exists for the many engines still in use. These are principally a development of the German Argus As 10C inverted vee-eight of 260 h.p., and the all-French 9NH radial of 220 h.p., the latter being used in the S.E. Alouette helicopter.

S.E.P.R. *Société d'Etude de la Propulsion par Réaction, 37 Rue des Acacias, Paris.* This is an independent firm specializing in rocket propulsion. Nearly all their present work is directed to the development of bi-fuel motors for intercepters and missiles.

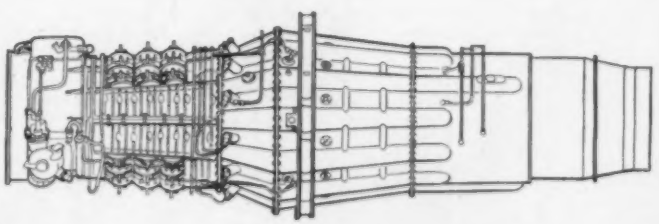
One of the most highly developed French supersonic test-vehicles is the Matra M.04, and this 1,100 m.p.h. aircraft is powered by an S.E.P.R. liquid-fuel rocket developing a thrust of 2,750 lb. Fuel and oxidizer are blown from their welded-steel tanks by compressed air, the normal duration of burning being 14 seconds.

A general similar motor for piloted applications is the S.E.P.R. 251, illustrated on p. 464. The two fuels are stored in tanks mounted on the airframe, in the S.O. 6025 test-bed both fuel and oxidizer were contained in tanks faired into the front of the motor, but the later Espadon S.O. 6026 has added wing-tip tanks for rocket fuel, giving a much longer duration. It was

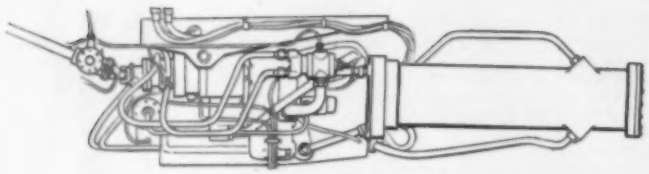
Leduc 021 ramjet. Note: The ramjet forms the entire fuselage of this aircraft. Diameter of duct, 8ft; length of duct, about 28ft; design speed, "high subsonic"; mass flow, about 350 lb/sec; thrust, about 15,000 lb with all burners in operation.



Potez 8D-30 90-deg inverted vee-eight, with geared drive and supercharger. Bore, 4.92in; stroke, 4.72in; swept volume, 714 cu in (11.7 litres); width, 31.3in; height, 31.6in; length, 67.8in; dry weight, 739 lb; maximum power, 450 h.p. at 2,800 r.p.m. with 5.2 lb boost.

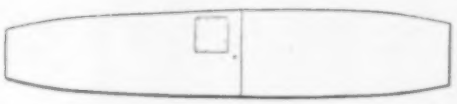


Rateau SRA-101 Savoie turbojet. Ten-stage compressor, twelve tubular combustion chambers and two-stage turbine. Diameter, 44in; length, approximately 160in as shown; dry weight, 2,293 lb; mass flow, 117 lb/sec; pressure ratio, 6.3:1; maximum thrust, 8,800 lb at 9,500 r.p.m. with water injection, or 7,300 lb dry.



S.E.P.R. 251 bi-fuel rocket motor running on nitric acid and alcohol or petrol. Dimensions of chamber and weight of unit not available. Full-throttle thrust, approximately 3 000 lb. This single unit has been tested in S.O. 6025 and 6026 Espadons; a triple-barrel unit will power the S.O. 9050 Trident.

ARS pulsejet. Simple, flap-valve, resonant unit, with frequency of 45 c.p.s. Diameter, 15.75in; length, 120in; dry weight, 165 lb; maximum thrust at sea level, 396 lb consumption; about 2.54 lb/hr/lb (actual consumption 130 gal/hr).



S.600 subsonic ramjet. Simple, open-mouthed ramjet with two spray rings carrying four and eight burners, respectively. Diameter, 23.6in; length, 128in; dry weight, 160 lb; maximum thrust at sea level at 621 m.p.h., 1,320 lb, with s.f.c. of 5.09 lb/hr/lb (actual consumption, 1.9 lb/sec).

Aero Engines 1954 . . .

demonstrated at the last Paris Show, and the rocket left a 30ft orange flame.

A triple-barrel rocket, using 251-size chambers, is now being developed for the S.O. 9050 Trident intercepter. This installation will be controlled by varying the number of chambers to which fuel is supplied.

SFECMAS. *Société Francaise d'Etudes et de Constructions de Matériels Aéronautiques Spéciaux, Chatillon-sous-Bagneux, Seine.* This privately-owned company, derived from the former Arsenal de l'Aéronautique (which ceased to exist as a Government-owned organization on December 31st, 1952) has largely continued Arsenal's work in the same establishments. A great deal of largely-secret work is now going on, in the realms of power units, missiles and instrumentation.

ARS 12H. This inverted vee-twelve piston engine is an advanced development of the German Junkers Jumo 213. It retains the Junkers direct-injection fuel system, and has a low-pressure liquid-cooling system. Drive can be arranged for a single or contra-rotating airscrew, and a remote accessory gearbox drive is provided. The two-speed supercharger is mounted on a transverse axis. The 12H has been built in numbers for Noroit amphibians, and is still in limited production. With a swept volume of 35 litres it delivers up to 2,300 h.p. at 3,250 r.p.m. with 11 lb boost. The dry weight is 2,209 lb.

Ramjets. A wide variety of subsonic ramjets has been designed by the SFECMAS group, the two furthest advanced being the S.600 (600mm internal duct-diameter) and S.900. Both are similar in form, having plain open mouths and conventional interiors, the structure being in mild steel and light alloy, with a separate steel inner wall over the hottest part of the duct, about half-an-inch from the main structure. Flame-holding is achieved by mounting a small disc immediately in front of each injection nozzle to create turbulence; pressure-loss appears to be on the high side. The nozzles themselves are mounted on two concentric spray rings.

The S.600 was originally tested on a Ju88G, but SFECMAS have now been lent a Meteor NF.11 and much more advanced testing has been completed, with very satisfactory results.

The larger S.900 (also designated ARS 900 and O900) is generally similar in form to the 60 cm ramjet, and has completed some hours of ground running. With a diameter of 35.4in, length of 162.4in and dry weight of 242.5 lb, the S.900 gives an estimated net thrust of 2,510 lb at 621 m.p.h. at sea level, for an actual consumption of 4.4 lb of fuel per second.

Pulsejets. The ARS pulsejet is basically a much-refined development of the German Argus 014 (flying bomb) engine. A grid of spring-steel flapper valves is fixed at the intake, the latter being of acute venturi form, of small internal diameter. Initial firing is by a sparking plug, and the frequency is approximately 45 c.p.s. with 90-octane petrol as fuel. A fuel-pressure regulator is fitted, set to reach full throttle at 19,500ft. At present, valve life is 10 hr, and thrust remains about 95 per cent of the quoted figure during this time.

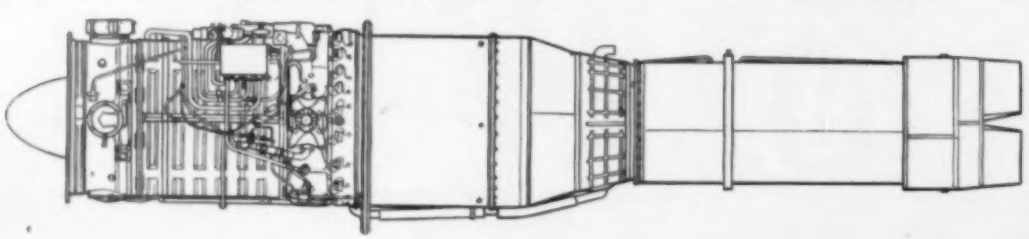
SNECMA. *Société Nationale d'Etude et de Construction de Moteurs d'Aviation, 150 Boulevard Haussmann, Paris 8e.* This national organization is probably the largest aero-engine combine on the continent of Europe. It was formed in 1945-6 by the amalgamation of two outstandingly famous engine companies, Gnôme-et-Rhône and Renault. The present work is as follows: at the big Kellermann factory in Paris the Atar 101D turbojet is in volume production, and Goblin and Ghost turbojets of Vampires and Aquilons (Sea Venoms) are overhauled; the plant at Billancourt (Seine) is in production with the 12S engine and its spares, and licence-produces the Bristol Hercules 758 and 759; and at Gennevilliers (Seine) a large forge and foundry supplies all standard types of forging and casting for the whole French aircraft industry. The SNECMA static- and flight-test establishment is at Mélun Villaroche.

Apart from the engines described below, SNECMA have developed a reverse-thrust device for turbojets, consisting of a series of curved-section rings surrounding the jet and a means of blowing the jet into the rings when required, as might be necessary on landing. This is accomplished by injecting a blast of compressed air, generally tapped from the engine compressor, which parts the issuing jet and causes it to strike the rings, which then produce a total deflection of some 130 deg. At full throttle, some 25 per cent of the full normal forward thrust is available for deceleration; the method has been tested during the past year to a total of 150 flight hours on five types of aircraft, although most of the development has been done with a Vampire. Significantly, the device has been used as an air-brake at speeds up to Mach 0.9.

Atar. Far and away the most important continental gas turbines, the Atar family are very-much-developed enlargements of the German B.M.W. 003, and it may be noted that SNECMA's gas-turbine technical director is Dr. H. Oestrich. The first Atar ran in 1948 and the 101B sub-type passed a 150-hr test in 1949 at 4,850 lb thrust. The 101B later gave 5,280 lb and was followed by the 101C at 6,200 lb, of which a small production series was made. The 101D was then developed with a full automatic control system and ice-protection, and this type is in full production for the Mystère II, Vautour and later aircraft, including the Baroudeur. As shown, it has, like all early Atars, a variable-area tailpipe controlled by a sliding internal bullet. Present production 101Ds have eyelid shutters arranged—unusually—as top-and-bottom components, and not left-and-right.

The Atar 101E is very similar, but has a maximum thrust of 7,300 lb with water injection; general refinement has also reduced the weight. The 101F is the 101D fitted with a

SNECMA Atar 101D turbojet. Seven-stage compressor, annular combustion chamber with 20 single burners each with a flame cup, and single-stage turbine. Diameter, 36.2in; length, 140.9in; dry weight, 2,094 lb; mass flow, 106 lb/sec; pressure ratio, 4.5:1; maximum thrust, 6,600 lb at 8,500 r.p.m. at sea level with a s.f.c. of 0.98 lb/hr/lb



SNECMA afterburner, arranged with upper and lower eyelid-type shutters, and delivering a total thrust of 8,380 lb. The latest Atar is the 101G, which is basically an afterburning 101E and rated at 9,260 lb thrust. Most of the present work is aimed at proving the 101E preparatory to mass production; perfecting the afterburning 101F; and developing "variable-section propelling nozzles, characterized by the absence of moving parts." The latter have been tested, as also has an Atar with thrust-reversal.

Vulcain. Closely resembling the Atar in general design, the Vulcain is a single-spool axial turbojet of impressive size and potential; it is, in fact, one of the biggest turbojets now running in Europe. Design began in 1951, and it was an initial requirement that the engine should be suitable for use in a variety of types of aircraft, including both intercepters and long-range machines.

The Vulcain incorporates all the thousands of hours of Atar experience, and is likewise unusually simple in mechanical design. The first engine was run on May 21, 1952, and, in November of that year, completed its acceptance tests at a rated thrust of 9,920 lb. While ground-testing of a number of Vulcains continues at 11,000 lb rating, flight trials are shortly to begin, the aircraft being an 80-ton Armagnac. Several important prototype aircraft are now being designed around this engine.

4 L. The SNECMA Régnier 4 L is a four-in-line, inverted, air-cooled engine which is extremely popular in France and is in full production. Equipped for arduous work in all weathers (including extended inverted flight), the 4 L has special heat-resisting valves, with sodium-cooled stems and stellited seats; the overhaul life is 800 hr, or up to 1,100 hr in certain conditions.

12 S. The SNECMA Renault 12 S is a fast-revving, air-cooled inverted vee-12, with a planetary reduction gear and single-speed supercharger. Many hundreds have been made for such aircraft as the SIPA S.12 and M.D.315 Flamant; the type is in production and gives up to 600 h.p.

14 X. The SNECMA 14 X stems from a long series of Gnôme-Rhône two-row radial engines, and is a particularly neat, compact and small-diameter power unit. Military and civil variants have been developed, the former having a higher supercharger-ratio; a special helicopter engine has also been fully developed and it is this type which is illustrated. All 14 X engines are made up as complete power units (*groupe motopropulseur*) and particularly advanced cooling and cowling forms have been designed. The direct-drive 14 X-H, as illustrated, can be used at any crankshaft angle between horizontal and vertical, and incorporates a clutch, ejector cooling, and cooling fan. The power quoted makes allowance for fan power, and the maximum power for one hour is 685 h.p. at "progressive r.p.m." and 560 h.p. at constant r.p.m. of 2,500. An odd feature is that valve push-rods for both rows are operated from the same cam ring.

Pulsejets. Valveless pulsejets of the Bertin type are remarkable power units, obtaining their thrust entirely by resonance, which is controlled solely by the profile of the duct interior. The early types of unit, such as the Escopette, employed a "recuperator," or U-tube with both outlets facing to the rear, mounted at the front of the main intake, so as to turn to useful thrust all the gas expelled from the front of the duct after each explosion. In the later Ecrevisse, the whole duct is bent back along itself, so that both propelling nozzle and intake face rearwards. Each expulsion of gas creates a depression inside the duct sufficient to induce a fresh charge of air, which is then mixed with fuel and ignited.

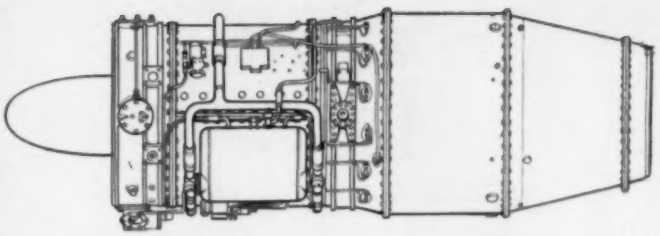
Development of the Ecrevisse and its successors is proving most encouraging. Flight trials have taken place on various gliders, and have proved that the units are properly developed and controllable, although tremendous noise is something of a problem.

Turboméca. *Société Turboméca, Bordes, Basses-Pyrénées.* Under the presiding genius of J. R. Szydlowski, this progressive firm have developed a unique range of small gas turbines which, beginning with aircraft turbojets, now embrace many spheres of propulsion, as well as a variety of static applications. The company was originally formed in 1938 to develop air compressors and superchargers.

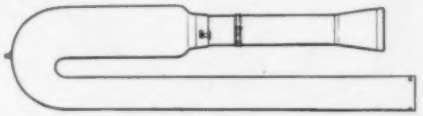
The first engine, the Piméné, was developed during 1948, and flew in a Fouga sailplane the next year. It set the pattern of the later engines, with its simplicity and ruggedness, and in its employment of a patented annular combustion chamber into which finely divided fuel was fed under centrifugal pressure from a disc which rotated on the compressor/turbine shaft. In addition to the engines described below, a variety of others have been developed for driving alternators, or other accessories, and for providing compressed air.

Turboméca engines are being made under licence in this country (by Blackburn and General Aircraft) and elsewhere.

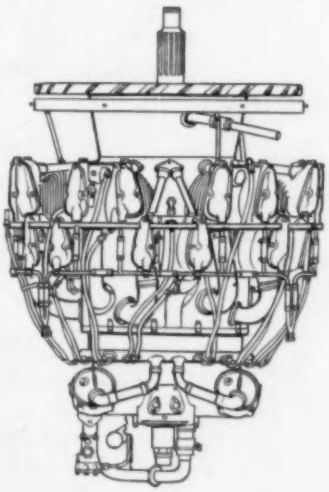
Piméné. This light turbojet developed 242 lb thrust at 35,000 r.p.m. Five were originally ordered by the French Air Ministry, and the fifth was the first French turbojet to pass the official acceptance test at Chalais-Meudon.



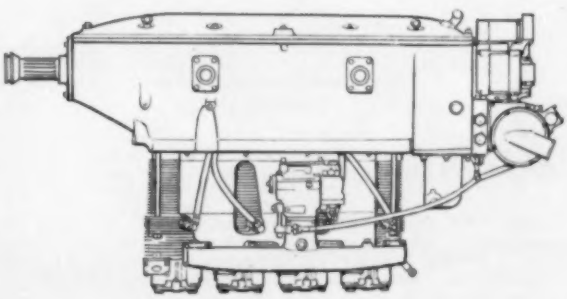
SNECMA Vulcain, turbojet. Axial compressor, annular combustion chamber with sixteen burners, and single-stage turbine. Diameter, 45.6in; length, 127.4in; dry weight, 3,360 lb; mass flow, over 170 lb/sec; pressure ratio, about 6 : 1; maximum thrust, 11,000 lb.



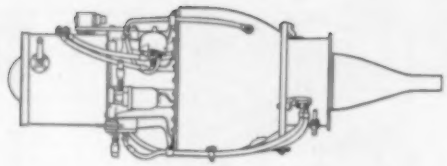
SNECMA Ecrevisse valveless pulsejet. Length, 97.5in; dry weight 22 lb; ground static thrust, 66.2 lb with s.f.c. of about 1.2 lb/hr/lb.



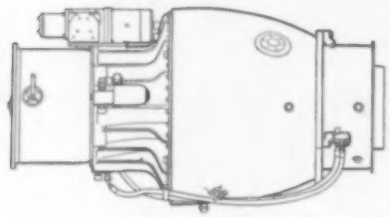
SNECMA 14 X-H fourteen-cylinder, supercharged, two-row, air-cooled radial, for rotary-wing applications. Bore, 4.8in; stroke, 4.57in; swept volume, 1,159 cu in (19 litres); diameter, 41.7in over cowling; height, 53.8in; dry weight, 1,095 lb without fan; maximum power, 790 h.p. at 2,700 r.p.m.



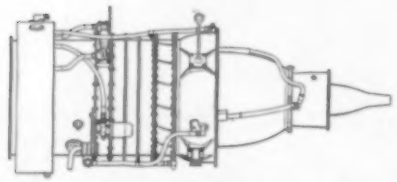
SNECMA Régnier 4 L inverted, four-in-line piston engine, ungeared and unsupercharged. Bore, 4.72in; stroke, 5.5in; swept volume, 384.4 cu in (6.3 litres); width, 19.7in; height, 29.9in; length, 53.5in; dry weight, 297 lb; maximum power, 170 h.p. at 2,500 r.p.m. (4 L-02).



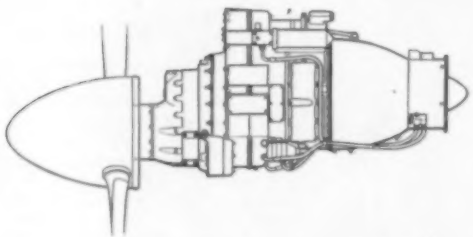
Turboméca Palas turbojet. Single-sided centrifugal compressor, annular combustion chamber with rotating fuel injector, and single-stage turbine. Diameter, 16.1in; length, 47.2in; dry weight, 159 lb; mass flow, 6.8 lb/sec; pressure ratio, 4:1; maximum thrust, 350 lb at 34,000 r.p.m. with s.f.c. of 1.1 lb/hr/lb.



Turboméca Marboré II turbojet. Layout as Palas. Diameter, 22.3in; length, 41.9in; dry weight, 293 lb; mass flow, 16.7 lb/sec; pressure ratio, 4:1; maximum thrust, 880 lb at 22,600 r.p.m. with s.f.c of 1.08 lb/hr/lb.



Turboméca Aspin II by-pass engine. Layout as described in text. Diameter, 23.8in; length, 63.5in; dry weight, 304 lb; mass flow, 46 lb/sec through intake, 6.6 lb/sec through main compressor; pressure ratio, 1.15:1 through single-stage axial fan, 3.8:1 through centrifugal compressor; maximum thrust, 900 lb at 35,000 turbine r.p.m. with s.f.c. of 0.52 lb/hr/lb.



Turboméca Marcadau single-shaft turboprop. Layout as Palas with added series of reduction gears. Width, 18in; height, 22in; length, without airscrew, 54.5in; dry weight, 308 lb; maximum power, 400 s.h.p.

Aero Engines 1954 . . .

Palas. Of similar overall size to the Piméné, the Palas can pass about 50 per cent more air, and has correspondingly higher thrust. It is in limited production for use in a series of booster power packs which have been fitted by several civil airlines under the wings or fuselage of DC-3s, Commandos and Bretagnes. These Palas booster units are fully cowled with a flush intake on the underside; they are made and marketed by the French nationalized SNCASO group.

Marboré. Logical development of the Palas has produced the bigger Marboré. The Marboré II is now in full production at Bordes for the Fouga C.M.170 trainer (subject of an "In the Air" article in *Flight* last week), and variants of the same engine are going into production at Blackburn and General Aircraft in England and Continental in America. The Marboré has also been exported to Yugoslavia, for use in that country's nationally-designed light jet aircraft. As it is the most important Turboméca engine, notes on its construction serve as a model for the other engines: intake air passes down a large-diameter light-alloy duct bolted to the front of the engine and then is compressed by the duralumin two-piece impeller, which is splined to a tubular turbine shaft. The combustor is a simple annular drum containing a perforated flame-chamber into which fuel is flung, at right angles to the air stream, from the edge of the disc injector. Production Marborés have very adequate accessories and controls, most of the latter being of Turboméca design.

Aspin. A true by-pass engine, the Aspin has been steadily developed but is not yet in production. All the intake air passes through a row of variable-incidence guide vanes, following which are a row of stator blades and a further row of straightening vanes. The air is then compressed in a single row of axial blades driven through reduction gears (0.2645:1) from the main rotating assembly. A flow-divider then by-passes 85 per cent of the flow around the combustion chamber; the remainder of the engine is generally similar to the Palas.

Palouste. This is basically a Palas arranged as a supplier of compressed air rather than of jet thrust. A large hole is cut in the top of the outer shell above the combustion chamber, from which a large-diameter duct can lead the air away; delivery is about 1.9 lb/sec at take-off r.p.m. of 35,000, and automatic regulation couples delivery and tailpipe temperature. The Palouste is used in the Djinn tip-jet helicopter.

Artouste. This is a shaft-drive engine which exists in two sizes; Artouste I of 280 h.p. and Artouste II of 400 h.p. The main gas-producer section is similar to that of the turbojets, but spur reduction gearing steps the speed down to 6,000 r.p.m. at the output shaft. Apart from its use as an auxiliary power unit, the Artouste is used as a primary aircraft power unit (*vide* Continental, U.S.A.).

Marcadau. As the output-shaft speed of the Artouste is too high for an airscrew, the Marcadau has been developed, consisting basically of an Artouste II with an extra gearbox, further reducing the drive to a maximum of 2,500 r.p.m. The airscrew shaft is over five inches below the main axis of the engine.

Ossau. Largest of the Turboméca power units to date, the Ossau gives a thrust of some 2,200 lb, or over 2,500 lb with an exceptionally neat afterburner. It follows previous Turboméca practice except for the employment of a form of diagonal-flow (basically centrifugal) compressor with axial delivery. No application has been announced.

ITALY

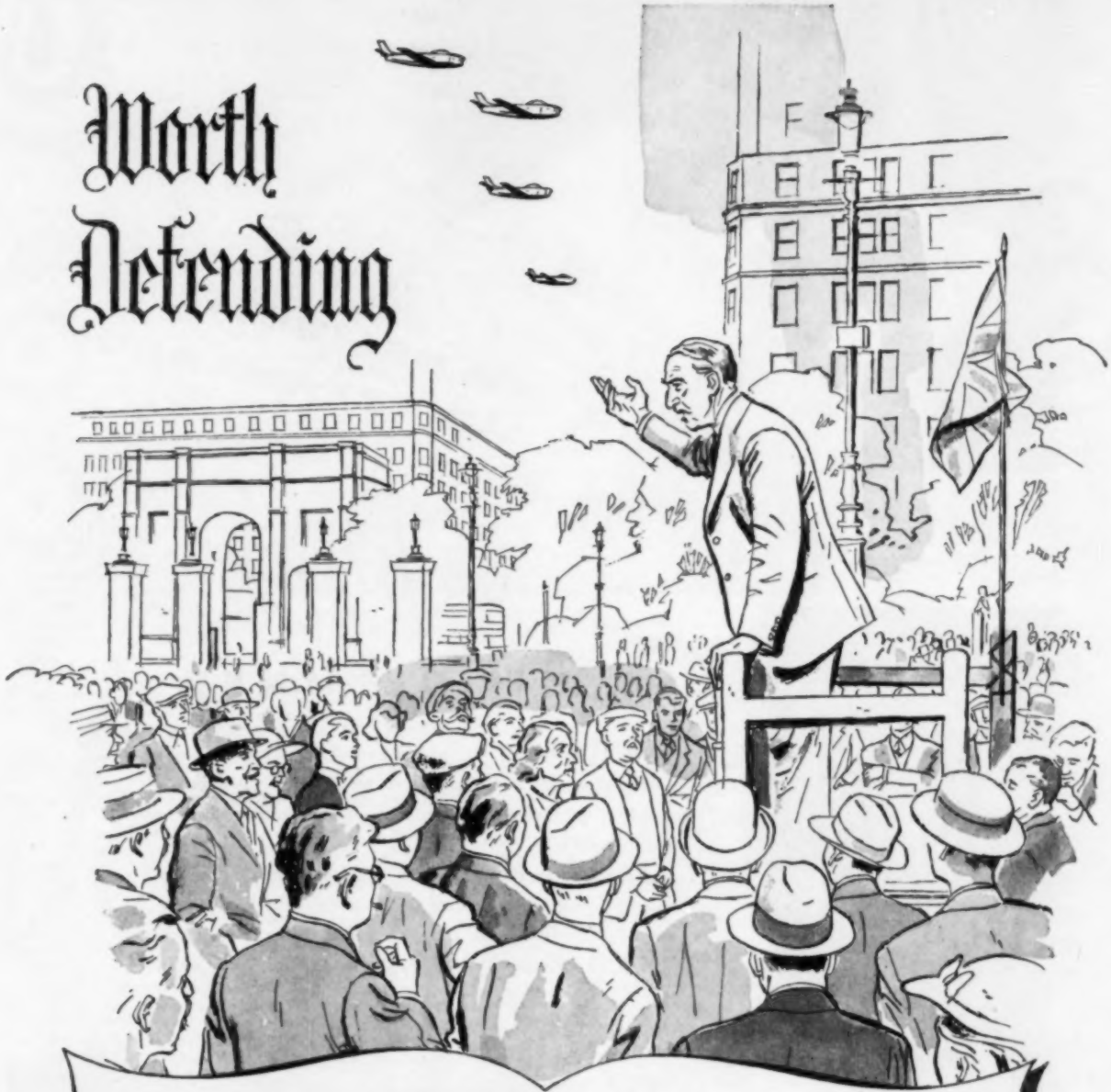
Alfa. *Sociéta per Azione Alfa Romeo, Milan.* This famous company have made some 15,000 aero engines, over 11,000 of which were powerful radials for World War II. Since 1943, however, production has been confined to moderate output of three basic types: the four-cylinder 110Ter (Mk 3), the 115 Ter (illustrated) with six cylinders of the same size as the 110, and the inverted vee-eight Alfa 121 of 415 h.p., at 3,000 r.p.m. Of these the 115Ter is the most important, and it is being built in some numbers for the Italian air force.

Ambrosini. *S.A.I., Ing. A. Ambrosini & C., Milan.* Since 1945 this successful aircraft company has designed, and is in limited production with, two very small horizontally-opposed engines, one being a four-stroke flat-four of 75 h.p. and the other a two-stroke flat-twin of 22 h.p.

Fiat. *Sociéta per Azione Fiat, Turin.* This immense automotive firm, which makes some 70 per cent of Italy's cars, has not manufactured aero engines of Fiat design since the war. Major effort has been directed towards licence-production of the de Havilland Ghost turbojet, and a complete new gas-turbine factory has been established, as well as comprehensive test equipment. In addition to Ghost manufacture, Fiat overhaul the large number of Goblins in Italian service; they also hold an "offshore" contract to make spares for the Allison J35-A-29 turbojet which powers NATO Thunderjets. They are now believed to be developing a gas-turbine aero engine of their own.

Ghost. During the formative months of "offshore procurement" it was expected in Italy that the Venom in one form or another would be produced against such a contract by the Italian industry. To meet the engine requirement, Fiat and Alfa Romeo tooled-up for the Ghost but, following the decision not to make the Venom in Italy, Alfa Romeo withdrew. Fiat, however, have since gone ahead, financing the tooling themselves, to make about 70 Ghost 48 Mk Is for the SNCASE Aquilon, or French-built Sea Venom. The engine is very similar to the Ghost 103, and retains standard British accessories; the

Worth Defending



FREEDOM OF SPEECH

"I disapprove of what you say, but I will defend to the death your right to say it!"
—VOLTAIRE

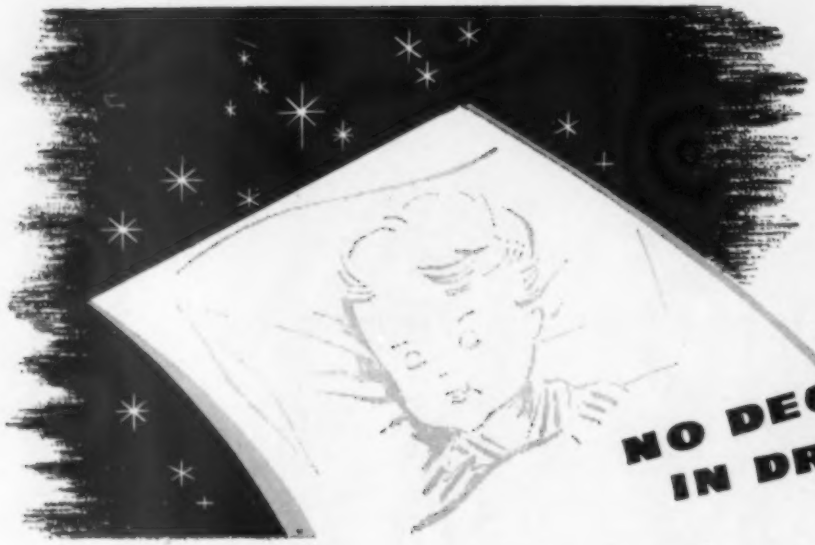
Freedom of Speech—the right to champion one's political views . . . to protest acts of government . . . to express new ideas or defend old ways . . . these become "crimes" and are hastily silenced wherever totalitarianism reigns . . and liberty of thought and conscience is no more.

Consider the liberty which we, in the free nations, enjoy . . . to speak out against wrongs . . . to speak up for what is right! Our Freedom of Speech is the great keystone of true democracy. Our Freedom of Speech is *worth defending!*

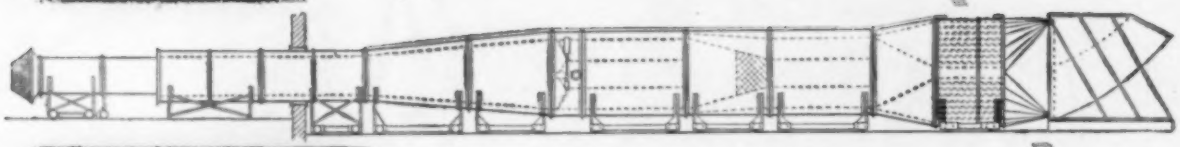
C-L CANADAIR LIMITED

CANADAIR
— AIRCRAFT MANUFACTURERS —
LIMITED, MONTREAL, CANADA

One of a series dedicated to the survival of freedom — Reprints on request. — European Representative, J. H. Davis, Princes House, 190 Piccadilly, London, W.1., England.



NO DECIBELS IN DREAMLAND

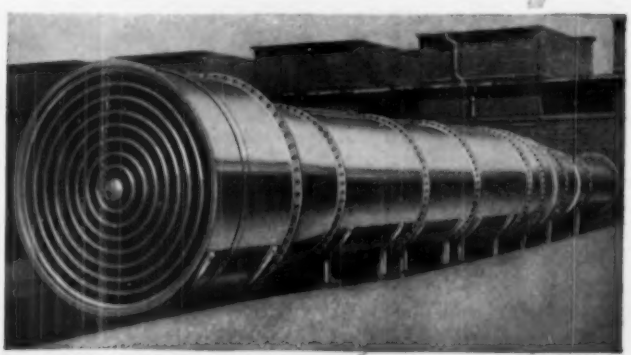


THE CULLUM DETUNER

As this child sleeps, who would guess that not so far away a new jet engine is roaring on its test bed? It disturbs no-one; for a Cullum Detuner mutes its shattering whine to a gentle rumble.

Super-priority defence production often demands all-night engine testing. And Cullum Detuners (already in regular use by Rolls-Royce, de Havilland, Armstrong Siddeley, the R.A.F. and Admiralty) are helping to make it practicable.

Photograph by courtesy of the de Havilland Engine Company Limited.



DETUNERS LTD

Flowers Mews, London, N.19. ARChway 2662-5

Efficient offices have Acoustic Tile ceilings by Horace W. Cullum & Co., Ltd

Aero Engines 1954 . . .

Italian sub-contracting industry supply detail parts such as ball bearings.

Piaggio. *Piaggio, S.P.A., Genoa.* This aircraft firm has a licence from the American Lycoming company to make the 190 h.p. direct-drive and 260 h.p. geared flat-six engines of the 0-435 series.

SWEDEN

Flygmotor. *Svenska Flygmotor A.B., Trollhätten.* Flygmotor, or S.F.A. as they are colloquially known, hold production licences from de Havilland in respect of the Goblin and Ghost turbojets. The Goblin is out of normal production, and the Ghost is described below. The Trollhätten factory is now being largely re-tooled for licence-production of the Rolls-Royce Avon, initially for the Saab A-32 Lansen and possibly also for a selected fighter of British design. The Avon will be very similar to the RA.7, and its production is necessitating extensions to the Flygmotor plant to accommodate the extra machines needed for axial work.

Flygmotor once had an engine of their own under development and, when this was abandoned, helped STAL with the Dovern. They have also developed a light and efficient afterburner control system, in which reheat fuel is governed electro-hydraulically as a function of turbine pressure ratio.

Ghost R.M.2. Flygmotor have made this type of Ghost for some years under D.H. licence, the British company receiving a royalty on each engine. But Flygmotor have had an almost completely free hand, and are virtually self-sufficient in this work. The Saab J-29 fighter has a single intake-duct, and consequently the R.M.2 looks rather like a Comet engine but, as it is a fighter unit, it has no British equivalent. Flygmotor have carried out their own modifications on the Ghost, but the accessories—including a Lucas fuel system—are all British, licence-produced in Sweden.

Bifurcated-intake Ghosts, virtually identical with our Ghost 103, are now also being built, for shipment to England and installation in Chester-built Venom night fighters destined for Sweden. Altogether, Flygmotor have done a fine job with the Ghost, of which they have already made some 600.

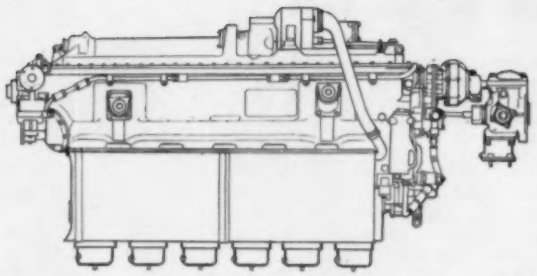
STAL. *Svenska Turbinfabriks AB Ljungström, Finspong.* The STAL company began aircraft gas-turbine development immediately after the war, and the first engine actually built—a small axial turbojet named the Skuten—was running in 1948. This was largely a research engine, with the knowledge from which the much larger Dovern was designed. The Dovern itself is a truly remarkable achievement, and well reflects the native ability of the Swedes as engineers. No one would claim the Dovern to be a peer of the latest Avon, but it is at least a fine, modern engine, and it is thoroughly Swedish; STAL, at least, know what it means to develop a modern axial engine absolutely from scratch up to the point at which it is ready for production.

The Dovern has at present completed about 4,000 hr of running, including over 300 in a Lancaster test-bed, which was supplied by Air Service Training. It must be disheartening to STAL to have the Avon put into production in Sweden in place of their own engine, satisfying as it may be to ourselves. STAL are reported to have a larger turbojet under development, but this is unconfirmed.

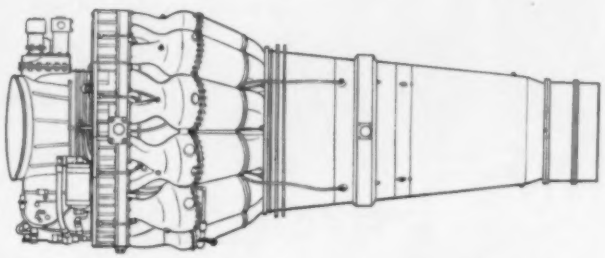
Dovern. Although quite conventional in conception—being similar to an Orenda or Avon RA.1—the Dovern has several unusual features. The compressor casing is made not as two longitudinal halves but as two barrels joined around their mutual periphery; all blading and casings are of steel. In line with the seventh stage of blades are four automatic blow-off valves while, in the Dovern IIB and IIC, a pipe leads hot air from the last stage round to the front end to provide complete ice protection. A Lucas fuel system is fitted, and the starter is either a Rotax electric or B.T.H. cartridge unit; Rotax and Lodge supply the shielded high-energy ignition. A 70 h.p. remote-gearbox drive is standard. The Dovern IIC has a STAL afterburner and gives about 10,200 lb thrust.

CZECHOSLOVAKIA

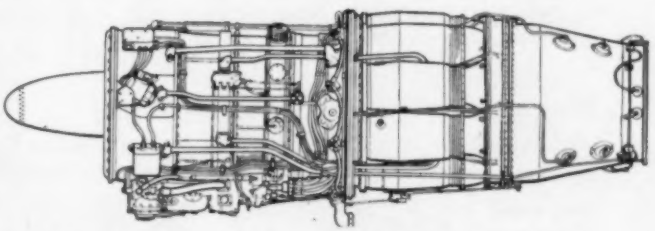
C.Z.A.L. *Ceskoslovenské Závody Automobilové a Letecké, Krizikova 38, Prague X.* All the former Czech manufacturers of aero engines, together with the remainder of the aircraft and automotive industry, have been placed under the direction of this central office, and all the products of the industry are marketed by Motokov, Ltd., a national light-engineering sales organization. It is almost certain that the VK-1, and its variants (developments of the Rolls-Royce Nene), are in production in Czechoslovakia, and it may be that more recent axial engines of Russian design are also being built. The only units about which anything tangible is known are the light piston engines discussed below.



Alfa Romeo 115Ter six-cylinder inverted in-line piston engine, ungeared and unsupercharged. Twin carburettors. Bore, 4.65in; stroke, 5.5in; swept volume, 560 cu in (9.2 litres); width, 19.6in; height, 32.5in; length, 64.7in; dry weight, 514 lb; maximum power, 225 h.p. at 2,400 r.p.m.



Fiat Ghost 48 Mk 1 turbojet. Single-sided centrifugal compressor, 10 combustion chambers and single-stage turbine. Diameter, 53in; length, 130.5in; dry weight, 2,175 lb; mass flow, 88 lb/sec; pressure ratio, 4.5:1; maximum thrust, 4,850 lb at 10,250 r.p.m. with s.f.c. of 1.09 lb/hr/lb.



STAL Dovern II turbojet. Nine-stage compressor, nine combustion chambers and single-stage turbine. Diameter, 43.1in; length, 151.6in; dry weight, 2,635 lb; mass flow, 121 lb/sec; pressure ratio, 5.2:1; maximum thrust, 7,275 lb at 7,200 r.p.m. with s.f.c. of 0.92 lb/hr/lb.

Praga. The Praga D, air-cooled flat-twin engine is used in numerous light aircraft, including some few in this country. Giving 75 h.p. at 2,650 r.p.m. it is capable of operation on inferior fuels of 72 octane rating. It is in small series production for Czech and other touring and training aircraft.

Walter. The Walter engines, to the classic Gipsy/Cirrus formula, have been made in large numbers over the last ten years and they enjoy a high reputation. Three basic types are being made, the Mikron (an inverted four-cylinder unit of 149 cu in capacity giving 65 h.p.), the Minor 4-III, described and illustrated, and the Minor 6-III (generally similar to the Minor 4-III, but with six cylinders, of 364.3 cu in total capacity and giving 160 h.p.).

SWITZERLAND

UNTIL 1948 the only important aero engines made in Switzerland were the Saurer of Hispano-Suiza-derived liquid-cooled vee-12 units, of which the 1,250 h.p. YS-2 was the most widely used. Since the war, however, the de Havilland Goblin turbojet, and later the Ghost, have entered service with the Swiss Air Force. The D.H. Engine company issued a licence to the Swiss Service Technique Militaire for the manufacture of the Ghost in Switzerland. The principal company concerned is Sulzer Bros., Ltd.,

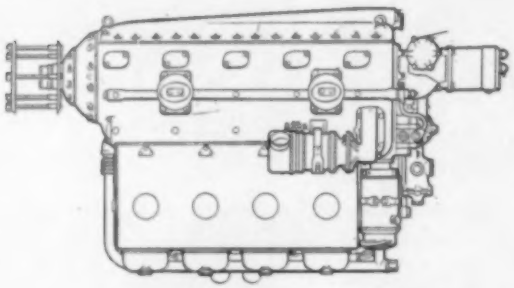
Aero Engines 1954 . . .

who are now fully tooled and are assembling the first engines. The chief sub-contractors are Adolphe Saurer, A. G. and Delaney Gallay (Geneva), the latter also supplying Nene flame-tubes to Hispano-Suiza. Sulzer are also in production with Goblin spares.

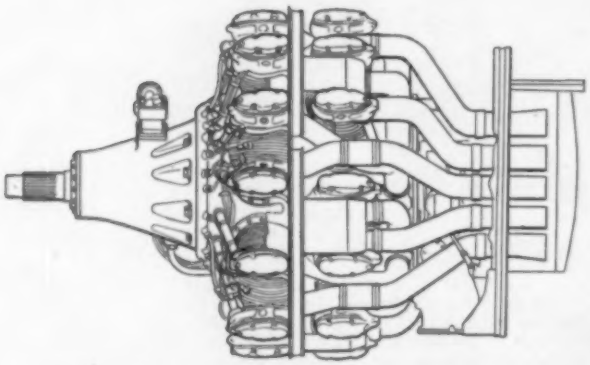
BELGIUM

F.N. *Fabrique National d'Armes de Guerre, Herstal.* In May 1949, the famous Belgian armament firm F.N. signed an agreement to supply Rolls-Royce Derwents for Benelux Meteors (this was before the formation of the NATO air forces). The Meteor 8 has since been built by Fokker, with major assistance from Avions Fairey, to a total of 348, and all the power units have come from F.N. British Derwent parts were assembled and run in November 1949; the first all-Belgian Derwent 8 finished its tests on February 21, 1951, and the hundredth on June 20 of the same year. Production to date may be in four figures.

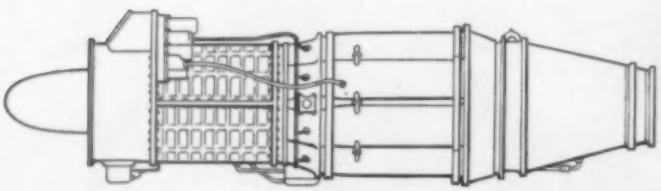
F.N. are now completely re-tooling for production of the Rolls-Royce Avon, in a model similar to the RA.7R, for "offshore" Hunters, of which 460 are to be built by Holland and Belgium combined.



Walter Minor 4-III four-cylinder inverted in-line air-cooled piston engine, ungeared and unsupercharged. Bore, 4.13in; stroke, 4.53in; swept volume, 247.9 cu in (3.98 litres); width, 15.7in without bearers; height, 24.9in; length, 40.63in; dry weight, 199 lb; maximum power, 105 h.p. at 2,500 r.p.m.



ASH-82FNW 14-cylinder, two-row radial, geared and fitted with two-speed supercharger and direct fuel injection. Bore, 6.125in; stroke, 6.1in; swept volume, 2,514 cu in (41.2 litres); diameter, 49.6in; length, 82.7in; dry weight, 1,984 lb; maximum power, 1,850 h.p. at 2,500 r.p.m. with 9 lb boost.



Omiya Fuji JO-1 turbojet. Eight-stage compressor, eight "cone-type" combustion chambers and single-stage turbine. Diameter, 26.8in; length, 110in; dry weight, 991 lb; mass flow, 39.7 lb/sec; pressure ratio, turbine pressure ratio (*sic*) given as 2.3:1; maximum thrust, 2,205 lb at 12,000 r.p.m. with s.f.c. of 1.11 lb/hr/lb.

SPAIN

E.N.M.A. *Empresa Nacional de Motores de Aviacion S.A., Barcelona.* This national organization took over the former Elizalde company two years ago and now make the Gipsy-major-like Tigre G-IVB of 150 h.p. and the 500 h.p. Sirio S-VIIA seven-cylinder radial, the latter in smaller numbers. Both these engines, which are ungeared and unsupercharged, are being progressively developed. In addition, two completely new air-cooled radials made their appearance a year ago: the 275 h.p. seven-cylinder Alcion of only 33in diameter (which, unlike other E.N.M.A. engines, is geared and runs at 3,000 r.p.m.) and the nine-cylinder, 53in diameter, direct-drive Beta, which gives 775 h.p. at 2,200 r.p.m.

U.S.S.R.

AS might be expected, a central office—the Ts.A.I.M.—handles all Russian aero-engine development, and all production is undertaken by State factories, which are now very widely dispersed throughout the Union. Nearly all the engines in use up to two or three years ago either owed much to non-Russian development or were direct copies of the products of other countries. There are indications that the engines now in production and under development are largely Russian in concept, although British, American and German influence is still very strong. The following notes give a general picture of the present position.

Gas Turbines. It is likely that the most widely used turbojet is the "Sovietized" Nene, which has been made in several forms to a total of some thousands of engines, and is still in production. The development of the Nene has naturally roughly paralleled that by Rolls-Royce, Pratt and Whitney and Hispano-Suiza: it is known that there have been changes in materials, several complete revisions of the gas path to accept a higher mass-flow, and provision for better cooling. Known variously as the RD-45, M-45 and VK-1, this basic engine powers the Mig-15 and several twin-engined types.

The most powerful gas turbines now running in Russia are probably axials, the first families of which were developments of established German units, the work being hastened by the assistance of numerous German designers. It is not unreasonable to assume, for example, that an engine generally similar to the French Atar has been developed from B.M.W. designs. There is also some evidence that large turboprops are running, although it is extremely doubtful whether they are yet in service.

Piston Engines. Apart from early, Hispano-derived vee-twelves, there exists a very complete range of highly developed air-cooled radials suitable for all powers from 100 h.p. up to reported maxima of 2,800 to 3,500 h.p., the latter being unconfirmed. The engine illustrated, the ASH-82FNW, is a fair example, and it generally resembles the Wright Cyclone R-2600, with some Twin Wasp influence and a greater output than either. It features direct fuel injection, after the German pattern, and a German (Askania) automatic boost control. Both civil and military versions exist. A more recent engine is the ASH-90 of at least 2,500 h.p. which was originally based on a Cyclone R-3350 from a B-29.

Other work. A great deal of work is probably going on in the fields of rockets, ramjets and such devices as afterburners and helicopter tip-drive systems.

ARGENTINA

THE national organization of all Argentine aircraft and aero-engine production is the Instituto Aerotecnico, at Cordoba. After the building of Wright and Siemens radials under licence, two "home-grown" engines were put into limited production. These are the I.Ae.16 El Gaucho, a nine-cylinder radial, ungeared and unsupercharged, of 450 h.p., and the I.Ae.19 El Indio, of identical layout but bigger, giving 620 h.p. The I.Ae also holds production licences for the Rolls-Royce Derwent 5 and Nene 2, but the number of turbojets actually produced is very small.

JAPAN

THE Japanese private engine companies produced several remarkably good high-power radials during World War 2, and were also introduced to the turbojet by Germany. Last summer, the Japan Jet Engine Company was established by Ishikawajima Heavy Industries, Fuji Industries and Ruji Precision Industries, to begin the design of turbojets in September 1953. The original capital was 160m yen (£160,000) and a government subsidy was applied for; when engines had been designed, the group would dissolve, leaving production to the parent company.

Meanwhile, Omiya Fuji Industries, of Saitama Prefecture, have produced a turbojet of their own. Illustrated here, the JO-1 is a development of the NE-20, which was a 1945 development of the German B.M.W. 003. A JO-1 is being built, using mainly American accessories, and is scheduled to run this autumn.

Specify-

BALL & ROLLER R&M BEARINGS

They Save in the long run

★★

THERE IS A BEARING FOR EVERY INDUSTRY'S NEED

★★ ROLLER JOURNALS
★ BALL JOURNALS
★ DOUBLE PURPOSE BEARINGS
★ THRUST BEARINGS
★ LINESHAFT BEARINGS
★ NEEDLE ROLLER BEARINGS
★ AIRCRAFT BEARINGS

OUR ENGINEERING DEPARTMENT WILL WELCOME THE OPPORTUNITY TO CONSIDER YOUR SPECIFIC APPLICATIONS AND MAKE RECOMMENDATIONS.

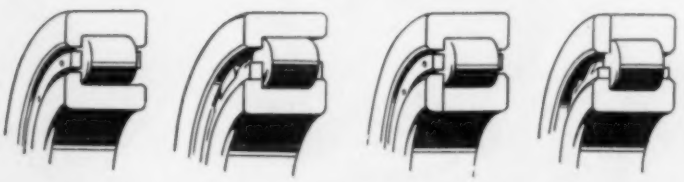
ROLLER JOURNALS

By reason of the "line" contact of the rollers with the tracks, roller bearings have, size for size, a considerably increased load carrying capacity as compared with a ball bearing of the same overall dimensions. The accuracy of the rollers and tracking surfaces enables speeds approaching those of ball bearings to be obtained.

The normal accepted type has a parallel outer ring and shouldered inner ring as shown above, but where conditions demand, bearings are made with a parallel inner ring and shoulders on the outer ring.

When it is necessary for a roller bearing to accommodate misalignment, bearings are supplied fitted with a spherical shell.

Roller bearings are usually required for journal loading only, but under approved conditions bearings made with additional shoulders or sideplates can be employed for location duties. Some of these are here illustrated.



RANSOME & MARLES BEARING CO., LTD., NEWARK-ON-TRENT, ENGLAND

K/RM 111

H

DE HAVILLAND
ADVANCED GUIDED WEAPON PROJECTS

Staff required for research and development work. Opportunity for enthusiastic qualified men to join expanding organisation offering permanence and advancement:—

ELECTRONIC CIRCUIT ENGINEERS capable of original circuit design and development. Applications are invited from Graduates with one or two years experience or experienced Electronic Engineers. (Reference 21)

TRIALS ASSISTANTS. Excellent opportunities for keen young men with experience on electronic equipment. Duties involve short periods of working away from base. Good chance for establishing sound position in a new field of engineering. Men with experience in the Services particularly welcome. (Reference 22)

AERODYNAMICIST with Honours degree and minimum of two years experience in aircraft or missile aerodynamics. Work involves interest in all aspects of missile dynamics. Sound engineering background an advantage. (Reference 48)

MATHEMATICAL ASSISTANT. Inter B.Sc. or G.C.E. at advanced level with aptitude for mathematics. (Reference 47)

ELECTRONIC ENGINEERS for technical administrative duties in Trials Division. Practical ability and experience more important than qualifications. Experience in organisation of small groups of technical personnel essential. Applicants must be between ages 28 and 35. Duties involve short periods of working away from base. Excellent prospects of promotion to senior positions in a new field of engineering for men with initiative and personality. (Reference 23)

PLANNING ENGINEER to examine design prior to prototype and pre-production manufacture. (Reference 36)

MECHANICAL ENGINEER to design and supervise manufacture of prototype test equipment. (Reference 37)

PLASTICS ENGINEER (Junior). Knowledge of chemistry and structures an advantage. (Reference 45)

RUBBER TECHNOLOGIST experienced in foam rubber development, qualified to degree or H.N.C. standard in physics and chemistry. (Reference 44)

WRITER (Ref. 28)
ILLUSTRATOR (Ref. 29)
CIRCUIT DRAUGHTSMAN (Ref. 30)

for newly established Technical Publications Section. Experience of Air Publication and/or instruction book work desirable.

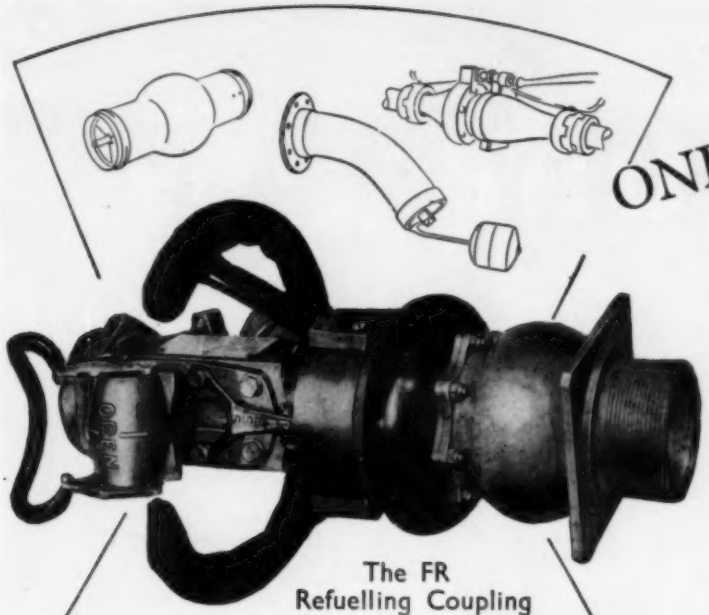
Please write in detail to
Personnel Manager (Technical Employment), de Havilland Propellers Ltd., Hatfield, Herts.
quoting reference number of position sought.

For Fuel Filtration on The Goblin Jet Engine, De-Havillands

USE AUTO-KLEAN FILTERS

AUTOKLEAN

AUTO-KLEAN STRAINERS LTD.
HOUNSLOW, ENGLAND
HOU 6441 (6 lines)



The FR Refuelling Coupling

The FR Refuelling Coupling gives positive and visual "on and off" indication. This feature together with nozzle flow-control and non-spill connection and disconnection, mean that no experience is required for use.

Conforms to International Pressure Fuelling Standards.

ONE ... TWO ... THREE — *and away*

Once the coupling units engage, on a typical FR pressure-refuelling installation, three major factors come into play to produce the high FR standard of performance: *ONE* — uniform flow, including closely-synchronised filling of individual tanks; *TWO* — maximum pressure-transference at every stage, owing to the low-loss design of FR components; and *THREE* — today's basic requirement in all refuelling—speed!

FR PRESSURE REFUELLING EQUIPMENT

FLIGHT REFUELLING LIMITED
Tarrant Rushton Airfield, Blandford, Dorset
Telephone: Blandford 501. Telegrams: Refuelling, Blandford
T.A.6365

in the air COOKERS · MOTORS GENERATORS · RADIO EQUIPMENT REFRIGERATORS · HEATING AND VENTILATION · LIGHTING FITTINGS · STEWARDS' CALL SYSTEMS · HEAVY ALLOY · AIRCRAFT CABLES · WATER HEATERS · URNS · OSRAM LAMPS, ETC.

on the ground AIRPORT LIGHTING AND CONTROL . GROUND TRAFFIC CONTROL · POWER EQUIPMENT AND CABLES · RADIO COMMUNICATION · NAVIGATIONAL AIDS · BROADCAST CALL SYSTEMS TELEPHONE COMMUNICATION · LIGHTING FITTINGS · HEATING AND VENTILATION · OSRAM LAMPS · COOKING EQUIPMENT AND ANY OTHER TYPE OF ELECTRICAL EQUIPMENT FOR AIRPORT BUILDINGS, ETC.

G.E.C.

ELECTRICAL EQUIPMENT FOR AVIATION

THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2

THE TUNGUM COMPANY LIMITED, Brandon House, Painswick Road, Cheltenham, Glos.

MARSTON PRODUCTS

are fitted to the world's leading aircraft

HEAT EXCHANGERS

'FLEXELITE' FLEXIBLE FUEL TANKS

RADOMES

and other components in laminated plastics.

In France, S.A. Fermeture Eclair, Marston Division, 6 Rue Stanislas Girardin, Rouen

MARSTON EXCELSIOR LTD., WOLVERHAMPTON ICI

(A subsidiary company of Imperial Chemical Industries Ltd.)

MAR 126

one thing leads directly to another!

A logical sequence—you might say. One cable end is "bound" to go direct to the other through a Hellermann Pressure Bung (Patent No. 696241) because cables remain in a continuous unbroken length. Cables are *permanently* identified too by Hellermann Twinlay Markers (to M. of S. Spec. EL1738). Please ask for Leaflets BH.501 and BH.29.

Hellermann LIMITED · CRAWLEY · SUSSEX

(A *Subsidiary of Bowthorpe Holdings Ltd.*) Tel.: Crawley 747/8/9

Specification 'PLUS'

Manufactured to full Ministry Specifications

PLUS mirror finish contacts

PLUS vacuum impregnated coil

PLUS stove enamel finish

The foremost "S" type relay for finish and dependability

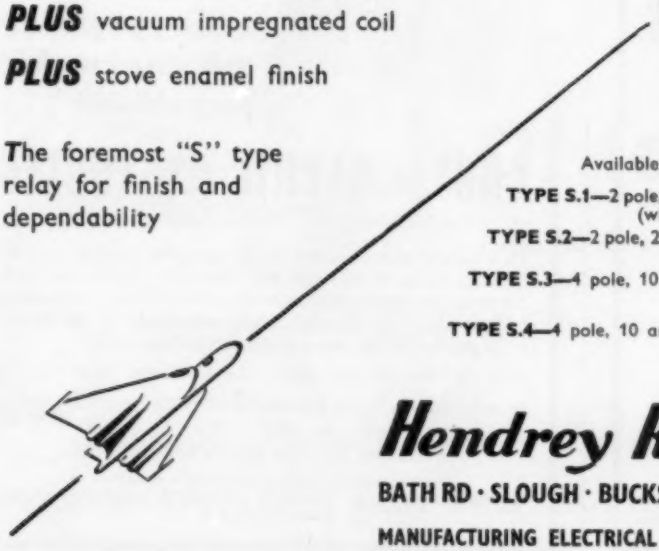
Available in 4 types:—

TYPE S.1—2 pole, 25 amps. changeover (with dust-cover)

TYPE S.2—2 pole, 25 amps. changeover (with moulded-cover)

TYPE S.3—4 pole, 10 amps. changeover (with dust-cover)

TYPE S.4—4 pole, 10 amps. changeover (with moulded cover)



Hendrey Relays Ltd.,

BATH RD · SLOUGH · BUCKS. Tel: BURNHAM 609/610

MANUFACTURING ELECTRICAL ENGINEERS · CONTROL & LABORATORY APPARATUS

IMPROVE your AIRFIELD

communications, links and systems by installing our

MOBILE EQUIPMENT

B.C.C. mobile equipment is designed and constructed with the same care and precision as used in the production of scientific apparatus. Our equipment is:—

RELIABLE
EASY TO MAINTAIN
SIMPLE TO OPERATE

BCC

BRITISH COMMUNICATIONS CORPORATION LIMITED

Second Way, Exhibition Grounds, Wembley, Middlesex. Telephone Wembley 1212

OXYGEN

BREATHING APPARATUS

for

High Altitudes

Mount Everest

Vital parts of the oxygen equipment of the 1953 and earlier expeditions were designed and supplied by the Company.

AIRCRAFT SAFETY BELTS

as supplied to

THE QUEEN'S FLIGHT

and

LEADING AIR LINES

AIR COMPRESSORS

SIEBE, GORMAN & CO. LTD.
LONDON
EVERYTHING FOR SAFETY, EVERYWHERE

TOLWORTH - SURBITON - SURREY

A NEW edition of an ever-popular photographic handbook . . .

PHOTOGRAPHIC ENLARGING

3rd Edition By David Charles, F.R.P.S.

This handy book describes in the simplest possible way the different types of enlarger and how they should be used. There is also much useful information on materials, accessories and the technique of making good enlargements. Of interest to all photographers, but particularly the amateur.

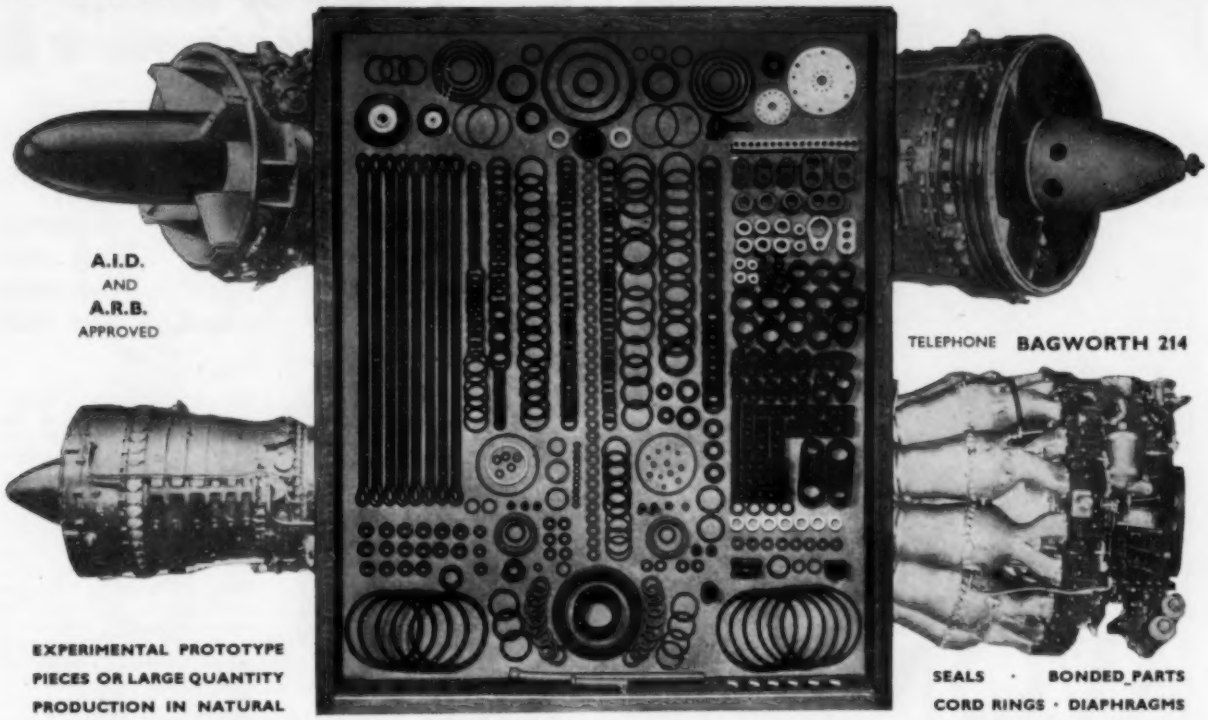
7½ in. by 5 in., 120 pp. 12 pp., plates. **6s. net** *By post 6s. 3d.*

By Arthur Nettleton, F.R.G.S. CASH FROM YOUR CAMERA *7s. 6d. net. By post 7s. 10d.*

Published for "Amateur Photographer"

From booksellers, photographic dealers or direct from:—
ILIFFE & SONS LTD., DORSET HOUSE, STAMFORD STREET LONDON, S.E.1.

PRECISION RUBBERS LTD. BAGWORTH LEICESTERSHIRE



A.I.D. AND A.R.B. APPROVED

TELEPHONE BAGWORTH 214

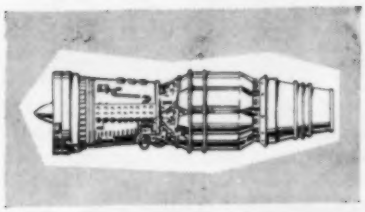
EXPERIMENTAL PROTOTYPE PIECES OR LARGE QUANTITY PRODUCTION IN NATURAL OR SYNTHETIC RUBBERS

A TYPICAL SET OF SYNTHETIC RUBBER COMPONENTS AS REQUIRED FOR A MODERN JET

SEALS · BONDED PARTS
CORD RINGS · DIAPHRAGMS
SILASTIC COMPONENTS

For Piston Engines

Air, Lubrication and Fuel Filters



Or for Jet Engines

Lubrication and Fuel Filters

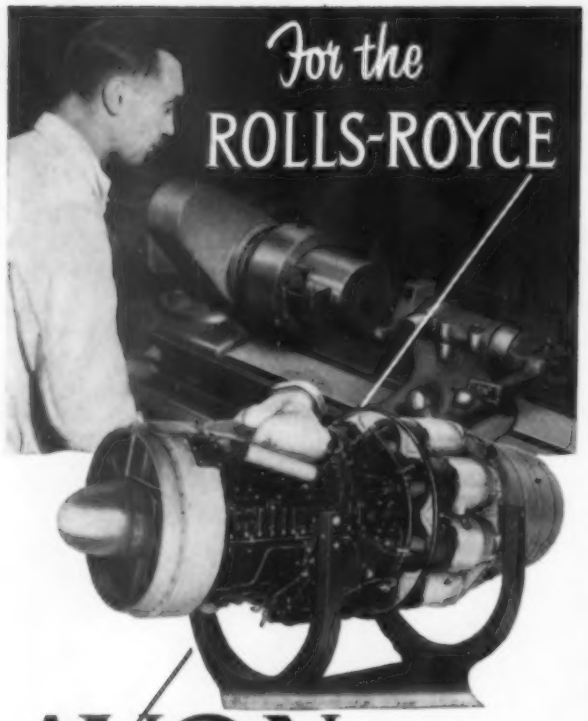
AND FOR TEST BED INSTALLATIONS TOO

Leading Manufacturers Specify VOKES

VOKES LIMITED . Head Office: GUILDFORD . SURREY

London Office: 40 Broadway, Westminster, S.W.1 Vokes (Canada) Ltd., Toronto · Vokes Australia Pty., Ltd., Sydney · *Represented throughout the World*

V129



For the ROLLS-ROYCE

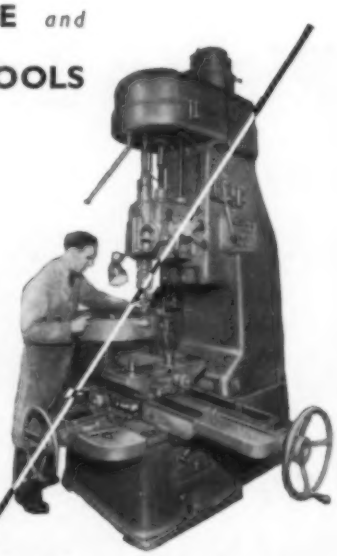
AVON JET ENGINE

We manufacture

JIGS, FIXTURES and GAUGES

also SERVICE and

ASSEMBLY TOOLS



Designers and Manufacturers of

JIGS, FIXTURES AND PRESS TOOLS

PROTOTYPE AND DEVELOPMENT WORK

ACCURATE PRODUCTION WORK

SPECIAL PURPOSE MACHINES

"LEYTOOL" HIGH QUALITY HAND TOOLS

Fully A.I.D. approved Ref. No. 793672/38.

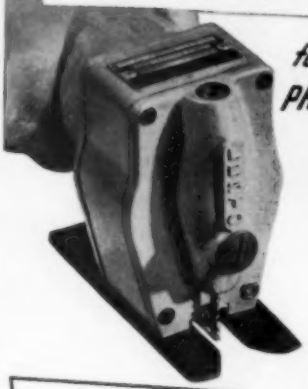
Leytonstone

JIG & TOOL Co. Ltd.

LEYTOOL WORKS, HIGH RD., LEYTON, LONDON, E.10

Phone: Leytonstone 5022-4

Proved by test... Backed by experience



for PRECISION CUTTING OF

WOODS • ALUMINIUM
BRASS • SHEET STEEL
PLASTICS • HARDBOARD
REINFORCED GLASS FIBRE
etc.

LESTO

THE ORIGINAL PORTABLE ELECTRIC HANDSAW

Made by SCINTILLA S.A. Switzerland

SCINTILLA LIMITED
Electric Hand Tools Division
20 Carlisle Road, London, N.W.9
Tel.: Colindale 8844

The LESTO Electric Handsaw is a superb example of the Swiss genius for precision tool-making. It cuts all shapes, no matter how complicated, at an amazing speed. Compactly designed, and weighing only 5¾ lb. for easy one-handed operations, it is a tool which will repay its purchase price many times over. As the result of many years of research, a range of 12 blades is available for specific use with metals, woods, plastics or hardboards. Fuller details of the Lesto range of portable electric tools, including Nibblers and Shears, are available on request.

The new Hand Tally Counter

This counter is extremely light, 1½ oz. (43.5 grams), including chain and finger ring. It is compact and can be carried in the waistcoat pocket.

Please write us for details of our standard mechanical and electro-magnetic counters

COUNTING INSTRUMENTS LTD.

5, ELSTREE WAY, BOREHAM WOOD, HERTFORDSHIRE

Telephone: ELSTREE 1382-3-4.

"Ah, now I see, sir!"

Our chairman was raised in the simple faith that every picture tells a story. So he is a firm believer in the value of WEST photo-copies to circulate information quickly and accurately.

The beauty about photo-copies, he says, is that they leave no room for mistakes or arguments. The design, plan, drawing, or message is down in black and white for the whole world to see, and once seen is never forgotten.

Why not use WEST photo-copies in *your* business for putting the whole staff 'in the picture'— with speed and accuracy? A copy can cost as little as 6d., and the job can be done within 24 hours. Reproductions can be supplied on paper, card, glass, transparent film, tracing-cloth and other materials; and bulky sets of documents can be reduced in size by photo-printing, for easy storage in bulk.

WEST

photo-copies

Send your work by post and in confidence to

A. WEST & PARTNERS LTD. (established 1888)
36, BROADWAY, WESTMINSTER, LONDON, S.W.1
Telephone: ABBey 3323

GAINSBOROUGH ENGINEERING CO. (OLDHAM) LTD.

and Associated Companies

G. CORNER & COMPANY LTD.
S. A. RHODES LTD.
WRIGLEY MOTORS LTD.

Engineers
Aircraft Component Manufacturers
Stainless Steel & Light Alloy Sheet Metal Fabricators

Direct Suppliers to:

AIR MINISTRY
MINISTRY OF SUPPLY
DEPARTMENT OF ATOMIC ENERGY

Many Leading Firms in the Aircraft Industry

The Group is AID and ARB approved and has a comprehensive plant and machine shop capable of producing a wide range of Aircraft assemblies including:—

AILERONS · ENGINE COWLINGS
FINS · RUDDERS · SELF SEALING
FUEL and OIL TANKS · WINGS
GROUND EQUIPMENT

Head Office:

ROSCOE STREET WORKS
OLDHAM, LANCS

Telephone: MAIN 2424 (3 lines)
Telegrams: "NEWAGE," OLDHAM

BIF
CASTLE BROMWICH
BIRMINGHAM
SEE OUR EXHIBIT
STAND No. D.302

H-R

KEY TO QUICKER PRODUCTION!

GLASS LAMINATES

Resin bonded glass fabric. Immensely strong. Impervious to normal temperature and humidity variations. Moulded **double curvature** drill, trim and assembly jigs a speciality.

Combined with

HY-DU-LIGNUM

We are specialists in the design and production of rubber press dies, drill and router templates, Hufford stretch press tools, etc. Increased board production makes HY-DU-LIGNUM immediately available for use in your own tool room. Board sizes now increased to 84" × 48".

Glass laminate drill and trim shroud with Hy-du-lignum base.

Photograph by courtesy of Motor Panels (Coventry) Ltd.

laminated-compressed
Hy-du-lignum
"the made-to-measure wood"

HORDERN-RICHMOND (SALES) LIMITED
Head Office: Hy-du-lignum Works, Haddenham, Bucks, England
Northern Office: Barton Arcade, Deansgate, Manchester

Telephone: AYLESBURY 1100–1102 *Telegrams: WINSTIX, AYLESBURY*

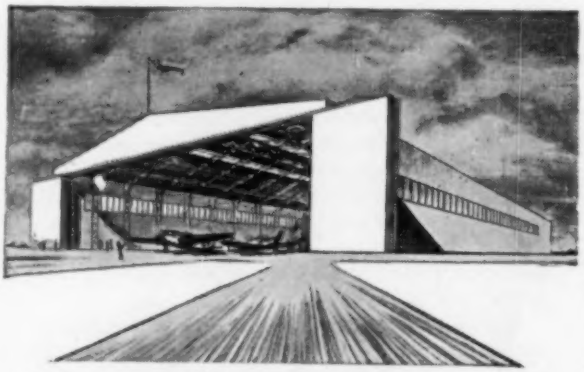
BERYLLIUM COPPER

CRINKLE washers

Heat treated and plated giving corrosion resistance with high degree of recovery in relation to load, and resistance to "set". Spring locking action suitable for electronic and instrument components. Size range ¼" to 8 B.A.

Prices and samples sent on request

CONTRACTORS TO THE ADMIRALTY • MINISTRY OF SUPPLY • & OTHER GOVERNMENT DEPTS.
DAVID POWIS & SONS LTD



GENERAL UTILITY

STEEL BUILDINGS

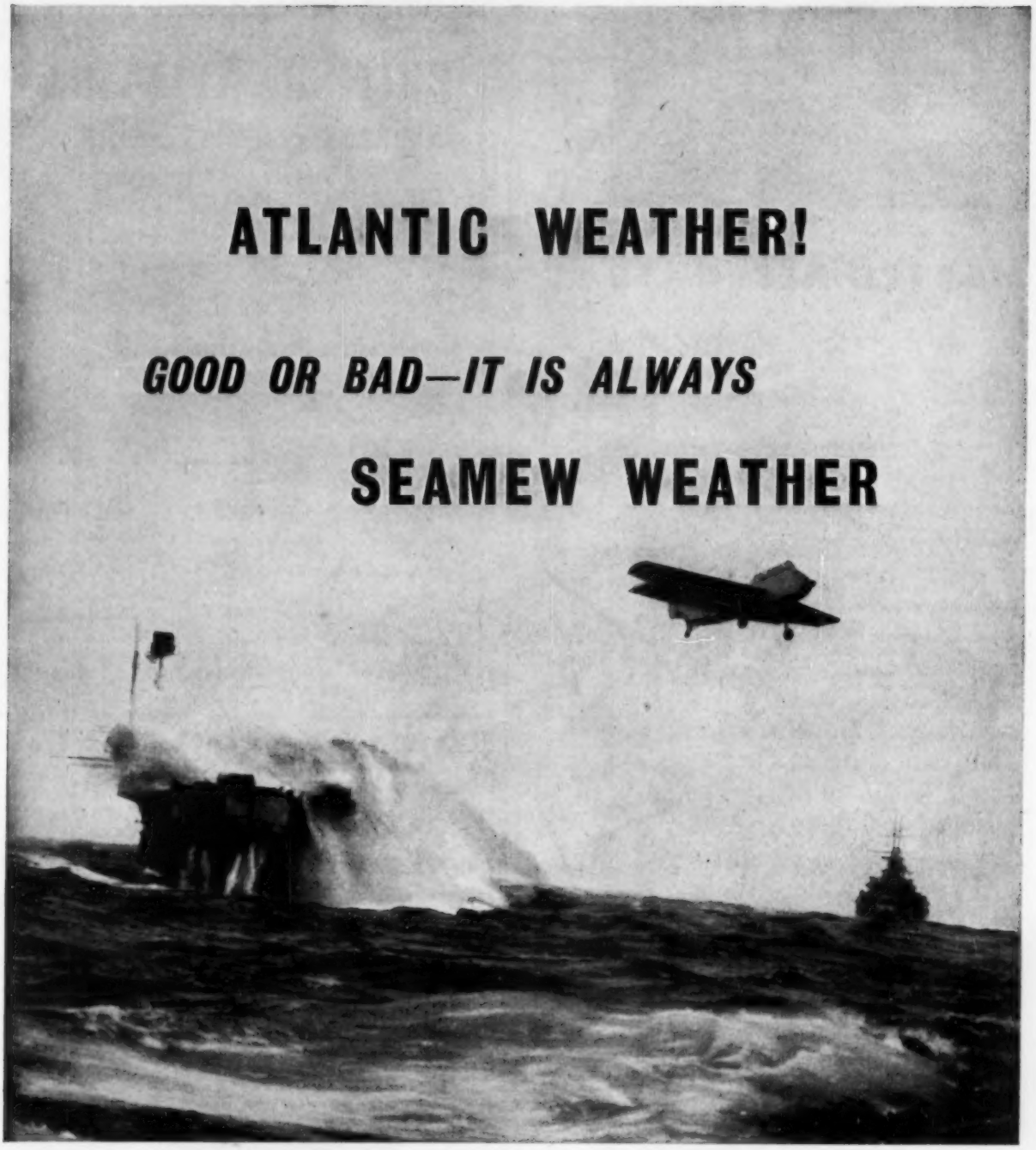
AND HANGARS

200 ft., 120 ft., 100 ft. and 80 ft. clear widths.
Any length and height.
All inside space usable and free from obstruction.
We erect.

WRITE OR PHONE:

BELLMAN HANGARS LIMITED

TERMINAL HOUSE, LONDON, S.W.1 SLOane 5259



The Short Seamew *ANTI-SUBMARINE AIRCRAFT*

Already in quantity production for the Royal Navy, the Short SEAMEW is designed and built to operate from aircraft carriers or coastal airstrips in all weather conditions. Powered by single Armstrong Siddeley Mamba turbo-prop engine.

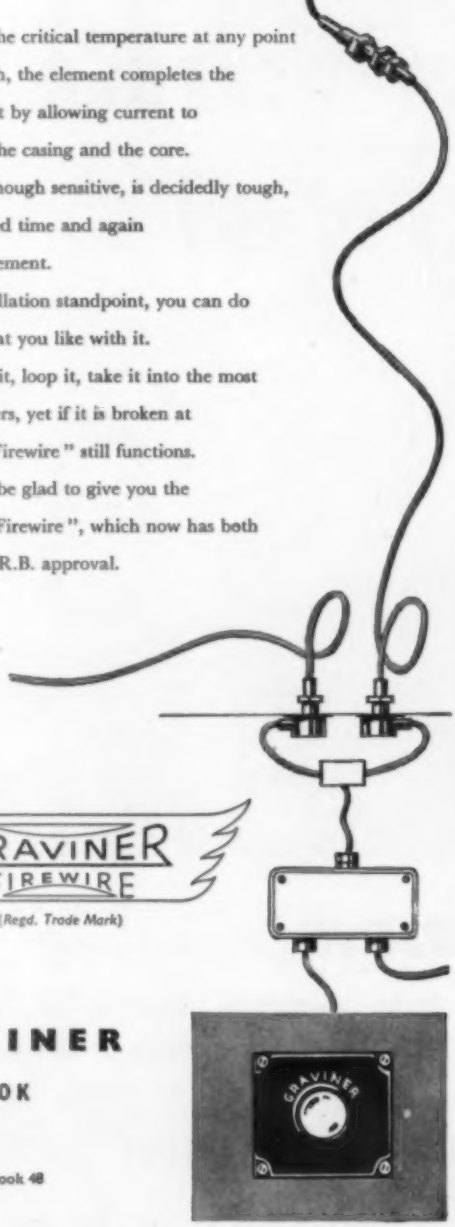
SIMPLE · RUGGED · EFFICIENT

THE FIRST MANUFACTURERS OF AIRCRAFT IN THE WORLD · Short Brothers & Harland Ltd., Queens Island, Belfast, Northern Ireland

HEATED RESPONSE

by sensitive element!

On reaching the critical temperature at any point along its length, the element completes the warning circuit by allowing current to pass between the casing and the core.
" Firewire ", though sensitive, is decidedly tough, and can be used time and again without replacement.
From the installation standpoint, you can do pretty well what you like with it.
You can bend it, loop it, take it into the most awkward corners, yet if it is broken at some point, " Firewire " still functions.
Graviners will be glad to give you the full story on " Firewire ", which now has both M.O.S. and A.R.B. approval.



GRAVINER FIREWIRE
(Regd. Trade Mark)

GRAVINER
COLNBROOK
BUCKS
Telephone : Colnbrook 48

THE
BRITISH AVIATION
INSURANCE COMPANY LIMITED

The oldest and largest office specializing in Civil Aviation

UNDERWRITER & PRINCIPAL SURVEYOR
CAPT. A. G. LAMPLUGH
C.B.E., F.R.Ae.S., M.I.Ae.E., F.R.G.S.

HEAD OFFICE
3-4 LIME STREET, LONDON, E.C.3
Telephone: Mansion House 0444 (6 lines)

BRANCH OFFICES

MONTREAL	JOHANNESBURG	VANCOUVER
276 St. James Street West, Tel: Lancaster 6135	London House, Loveday Street, Tel: 33-3048	626 West Pender Street, Tel: Tatlow 2167

TORONTO	CALCUTTA	BRUSSELS
61 Adelaide St. East, Telephone: Empire 4-4892	2 Hare Street, Telephone: Bank 6237	99 rue de la Loi, Telephone: 120,005

NEWTON-DERBY

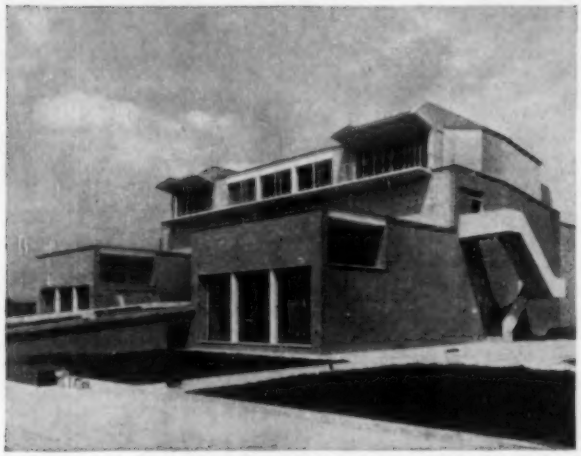
AUTOMATIC
VOLTAGE REGULATORS

Also makers of Rotary Transformers and Anode Convertors, Wind- and Engine-driven Aircraft Generators, High-frequency Alternators and High-tension D.C. Generators

ELECTRICAL PLANT SPECIALISTS

NEWTON BROTHERS (DERBY) LIMITED

* *Turbo-jet test plant at BRISTOL...*



* *SILENCING and thermal insulation system by*

MUFFELITE

The new BRISTOL turbo-jet test plant is generally regarded as being in advance of any test plant for a similar purpose in this country or any other.

The MUFFELITE silencing and thermal insulation system, designed and supplied by this company, suppresses the noise generated by two engines on test simultaneously and reduces the temperature of the engine exhaust gases by several hundred degrees Centigrade.

The success of any such scheme depends essentially upon collaboration, from its initiation, with the Architect and the Test Plant Design Engineers.

*** MUFFELITE System of Test House Silencing**

We have 15 years' experience of test house silencing. The assistance of our technical department and drawing office is freely available. This service can be most wisely employed at the design stage. Enquiries will incur no obligation.

The System is protected by British and Foreign Patents

MS2

CEMENTATION (*MUFFELITE*) LTD.,
39 VICTORIA STREET, LONDON, S.W.1 (*ABBey* 5726)

Problems of a Piping Designer

... and the Answers

Through our technical literature

our design staff

our engineers in the field

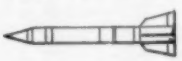
and our supply organisation,

we provide a complete "one-source" service in solving all flexible piping problems.

Significant of the value of this service is the fact that AVICA assemblies are installed on all the leading types of gas turbine power plants and air frames (both civil and military);

on test beds, test rigs

and research equipment throughout the industry; and in the rocket



and guided-weapon field.

Every day we are working on new problems—greater extremes of temperature and pressure, electronic devices for pipe line pressure measurement, for example. If you have any question concerning flexible piping we can almost certainly help you.

AVICA

FLEXIBLE PIPE ASSEMBLIES

Products include All-stainless Steel and Synthetic Rubber Flexible Pipes, Stainless Steel Bellows Assemblies, High Pressure Swivel Pipe Couplings, H.T. and L.T. Ignition Leads and Harness, Electrical Wiring Conduit Assemblies, Flexible Pipe and Cable Support Clips.

AVICA EQUIPMENT LIMITED
1 Adams Place, Holloway Road, London, N.7
Tel: NORth 4281 - Cables: Corpavia, London
T.A. 6182

★ A TOOL FOR PRECISION WORK

(As supplied to M.O.S., Admiralty and Leading British Aircraft and Motor Manufacturers)

RATCHET OPERATED

TORSION WRENCH

tightens nuts, bolts, etc.

- **accurately**
- **securely**

Wide range of bolts covered with single tool without need of resetting or additional apparatus.

GUARANTEED TESTED ACCURACY TO WITHIN 3% THROUGHOUT THE RANGE

Price, each

MODEL 60 Capacity 0— 60 pounds-feet £7.10.0 nett
Model 60S As above, but fitted with automatic signal switch £10 0 0 nett
MODEL 160 Capacity 20—160 pounds-feet £7.17.6 nett
Model 160S As above, but fitted with automatic signal switch £10 7 6 nett
MODEL 300 Capacity 20—300 pounds-feet £12. 0.0 nett
Model 300S As above, but fitted with automatic signal switch £14 10 0 nett
MODEL 600 Capacity 20—600 pounds-feet £23. 5.0 nett
Model 600S As above, but fitted with automatic signal switch £30 15 0 nett
and 0—60 pounds-inches

Smaller models are arranged for right- and left-hand drives.

M.H.H. ENGINEERING CO. LTD., Bramley, Surrey.
Telephone: BRAMLEY, SURREY, 2248

BRITISH EMULSIFIERS LIMITED
AND
ASSOCIATED COMPANIES

Specialists in all types of Sheet Metal Fabrication Design and Prototype Production for the Aircraft, Motor and Marine Industries

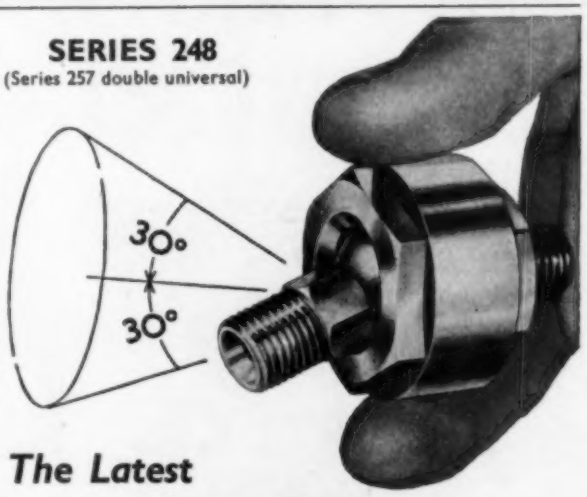
AERONAUTICAL PATTERN MAKERS
DIRECT SUPPLIERS TO M.o.S. & ADMIRALTY

A.I.D. & A.R.B. APPROVED

Jettison Tanks
Internal Fuel Tanks
Beams and Fairings
Filter Assemblies
Release Units
Wing and Tail Sections
General Aircraft Repair Work
Oil Dispensing Cabinets
Gas-Heating Cabinets
Cooling Cabinets
Ducting
Cooling Chambers

All enquiries to:
16/24 Brewery Road, London, N.7
Telephone : NORTH 4411/7

SERIES 248
(Series 257 double universal)



The Latest

UNIVERSAL HIGH PRESSURE COUPLING

Duralumin, brass, stainless or mild steel. Sizes ¼" to 2" BSP or to requirements. For services air, gas, hydraulic fluids and acids. Maximum test pressure 6000 PSI. Working pressure 4000 PSI

A.I.D. approved and Contractors to M.o.S.

"UNIJOINTS" (I.V.) & COMPANY
FORGE WORKS, 844, BATH ROAD,
CRANFORD, MIDDLESEX. *Phone HAYES 1203-2809*

Suppliers of

STAINLESS STEEL BARS and SHEETS

to all the

LEADING AIRCRAFT AND ENGINE MANUFACTURERS IN THIS COUNTRY

STAINLESS STEEL AND HEAT RESISTING BARS. BRIGHT DRAWN OR BLACK HEAT TREATED or ANNEALED

C. G. CARLISLE & CO. LTD.

629 PENISTONE ROAD, SHEFFIELD, 6 *Telephone: Sheffield 43615*

ZWICKY

AIRCRAFT RE-FUELLING EQUIPMENT...

NOZZLE

The importance of the nozzle to the efficient delivery of petrol and other fluids has led Zwicky technicians to give special attention to it. Our range includes both trigger operated and automatic cut-off types, for all rates of flow up to 100 gals. per minute.

ROTOR PUMP

Important features: **Positive displacement—Double helical gears — High volumetric and mechanical efficiencies — Non-pulsating— All bearings running in oil bath — 6 sizes from 15 to 600 gals. per minute.**

Zwicky Ltd., Trading Estate, Slough, Bucks.

TELEPHONE: SLOUGH 24481/2/3

POWER AND HAND PUMPS, MICRON FILTERS, PATENT HOSE REELS, SPECIALISTS IN PUMPING AND FILTERING EQUIPMENT.

Most British Power Plants Incorporate

Teddington

Controls

High temperature Gate Valves for control of compressor air tappings.

Hot Gas Valves for control of turbine tappings.

Engine De-icing Controls.

Cartridge Selector and Time Switches for turbo-starting.

Cycling Switches for electric de-icing of intakes.

Differential Pressure Switches and electro-pneumatic operated Gate Valves for fuel filter heating.

High temperature Solenoid Valves for reheat controls.

Teddington AUTOMATIC CONTROLS

TEDDINGTON CONTROLS LTD., CEFN COED, MERTHYR TYDFIL, SOUTH WALES. *(Merthyr Tydfil 666)*

There are no finer springs than Springs by Riley

RR FAMOUS FOR SPRINGS SINCE 1821

ROBERT RILEY LTD. - MILKSTONE SPRING WORKS - ROCHDALE
'Phone: ROCHDALE 2237 (5 LINES) *'Grams:* 'RILOSPRING' ROCHDALE

RING COLEY'S

HOUnslow 2266 • Ashton-u-Lyne 3664

FOREMOST

SCRAP METAL

MERCHANTS TO THE AIRCRAFT INDUSTRY

BUYERS OF ALL GRADES OF FERROUS AND NON-FERROUS METALS—ALSO OF ALL KINDS OF REDUNDANT STOCKS

COLEY METALS LTD.

INCORPORATING

IN THE SOUTH • R. J. COLEY & SON (HOUNSLOW) LTD., JUBILEE WORKS, CHAPEL ROAD, HOUNSLOW, MIDDLESEX

IN THE NORTH • R. J. COLEY & SON (NORTHERN) LTD., PARK WORKS, KING STREET, DUKINFIELD, CHESHIRE

General view of DE HAVILLAND DOVE AIRCRAFT modified for calibration duties for the MINISTRY OF CIVIL AVIATION

Illustration by courtesy of the Ministry of Civil Aviation.

Design, Construction and Installation by

Helliwells Ltd

THE AIRPORT · WALSALL · STAFFS

also at **STANSTED AIRPORT**

and **TREFOREST · PONTYPRIDD**

Telegrams: HELLIWELL·WALSALL · *Telephone:* WALSALL 4553 (6 lines)

●

The Helliwell Experimental Department which is approved by A.M. and A.R.B. undertakes the design, manufacture and installation of special purpose modifications and conversions. This department is equipped to carry out investigation and development work of all types.

"...and the electric power system is BTH throughout"

Aircraft manufacturers take no chances with electrical equipment. They specify BTH, relying on the reputation this firm's products enjoy in every branch of engineering.

BTH design complete electrical power systems and supply the appropriate equipment, including: AC and DC motors and generators, motor-generating sets with electronic regulators, gas-operated turbo-starters, Mazda lamps etc.

B T-H

Leading manufacturers incorporate

BRITISH THOMSON-HOUSTON

electrical equipment for aircraft

THE BRITISH THOMSON-HOUSTON COMPANY LTD.,
COVENTRY, ENGLAND
Member of the AEI group of companies

A 4758

FLIGHT and AIRCRAFT ENGINEER

PRESS DAY — *Classified advertisement "copy" should reach Head Office by* FIRST POST THURSDAY *for publication in the following week's issue subject to space being available.*

CLASSIFIED ADVERTISEMENTS

Advertisement Rates. 4/- per line, minimum 8/-, average line contains 6-7 words. Special rates for Auctions, Contracts, Patents, Legal and Official Notices, Public Announcements, Tenders 5/- per line, minimum 10/-. Each paragraph is charged separately, name and address must be counted. All advertisements must be strictly prepaid and should be addressed to FLIGHT Classified Advertisement Dept., Dorset House, Stamford Street, London, S.E.1.

Postal Orders and cheques sent in payment for advertisements should be made payable to Iliffe & Sons, Ltd., and crossed & Co.

Trade Advertisers who use these columns regularly are allowed a discount of 5% for 13, 10% for 26 and 15% for 52 consecutive insertion orders. Full particulars will be sent on application.

Box Numbers. For the convenience of private advertisers, Box Number facilities are available at an additional charge for 2 words plus 1/- extra to defray the cost of registration and postage, which must be added to the advertisement charge. Replies should be addressed to "Box 0000, c/o Flight," Dorset House, Stamford Street, London, S.E.1.

The Publishers retain the right to refuse or withdraw advertisements at their discretion and do not accept liability for delay in publication or for clerical or printer's errors although every care is taken to avoid mistakes.

Situations Vacant. The engagement of persons answering these advertisements must be made through the local office of the Ministry of Labour and National Service etc. if the applicant is a man aged 18-64 or a woman aged 18-59 inclusive, unless he or she or the employer is excepted from the provisions of The Notification of Vacancies Order 1952.

15 CHESTERFIELD ST., W.1
Telephone : GROsvenor 4841

AIRWORK LIMITED

AIRCRAFT SALES SINCE 1930

Consult us with confidence before Buying or Selling any type of Aircraft. You pay nothing for our advice and experience. We advertise for sale only aircraft available on our own premises or for which we have the sole selling rights.

PRESS NOTICE

APRIL 23rd ISSUE WILL CLOSE FOR PRESS WITH FIRST POST, TUESDAY, APRIL 13th

AIRCRAFT FOR SALE

W. S. SHACKLETON, LTD.

EUROPE'S LARGEST AIRCRAFT DEALERS

(Twenty-two years at this address and 129 different types of aircraft sold)

HAVE again an interesting selection of aircraft to offer—the machines mentioned below are typical examples:

D. H. DOVE. A really first class Dove, completely modified to date, very low engine hours, new Certificate of Airworthiness, 8 passenger seats, full V.H.F. and A.D.F. radio equipment. Available for inspection near London.

AVRO YORKS. Fully equipped with new Certificates of Airworthiness, completely overhauled nil hour engines and propellers and equipped as freighters or passenger/freighter convertibles.

MARK IB V. VIKINGS with new Certificates of Airworthiness and interior furnishings entirely to clients' choice, completely overhauled nil hour engines and propellers and ready for very swift delivery.

SHORT SANDRINGHAM flying boats. With new Certificates of Airworthiness, nil hour engines, fully equipped for 35 passengers.

CONSOLIDATED CATALINA flying boat. Immediately ready with International Permit to Fly and long-range tanks installed.

MILES MESSENGERS. With new Certificates of Airworthiness and low time or nil hour engines installed.

MILES WHITNEY STRAIGHT. Special aircraft fitted with multi-channel V.H.F. and radio compass installed.

AVRO ANSON I freighters. Extremely good, fully equipped with radio and with new Certificates of Airworthiness. Nil hour engines also available.

SEE also our advertisement in aircraft wanted.

W. S. SHACKLETON, Ltd., 175 Piccadilly, London, W.1. Tel.: HYDe Park 2448-9. Cables: "Shackhud, London." [0070

R.
K.
DUNDAS, Ltd.

AEROPLANES BY DUNDAS !!

FOR what purpose do you require an aircraft? For passenger transport or personal transport? For freighting? For training? For aerial top dressing or aerial photography? For towing gliders or advertising banners? Or for the sheer joy of flying? Wherever in the world you are or whatever your needs, we are sure to have the best 'plane for the job and we will be pleased to quote you F.O.B., C.I.F., or flight delivered.

AEROPLANES BY DUNDAS !!!

R.
K.
DUNDAS, Ltd.

29 BURY STREET, St. James's, London, S.W.1. Cables: "Dundasaero, London."
CROYDON AIRPORT. CRO. 7744. Cables: "Dundasaero, Croydon." [0559

CARTWRIGHT HAMILTON AVIATION DIVISION offer

LARGE selection of aeroplanes including Yorks, Oxfords, Austers, Proctors, Tiger Moths, also other light aircraft suitable for private flying and clubs. Comprehensive spares service available. 282 Kensington High Street, W.14. WEStern 0207-8. [0751

PROCTOR V with 12 months C. of A. Low engine and propeller hours. V.H.F. radio. Excellent condition. Best offer over £500.—Box 4449. [1839

DRILL HELMETS 25/-

GOSPORT TUBES 19/6

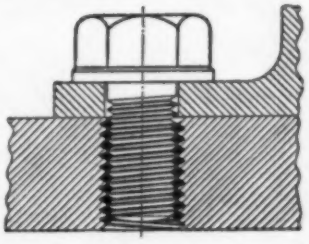
GOGGLES 246 9/11

Terms to Flying Clubs.

Send 3d. in stamps for illus. catalogue

D. LEWIS LTD. (DEPT. F.)
124 GT. PORTLAND ST., LONDON, W.1
Tel: Museum 4314 *Grams: Aviakit, Wesdo, London*

WIRE THREAD INSERTS



FOR NEW DESIGNS AND SALVAGE

CROSS MFG. CO. (1938) LTD.
COMBE DOWN, BATH
Tel.: COMBE DOWN 2355/6

R.A.F. OFFICERS
UNIFORMS
LARGE SELECTION IN STOCK
NEW AND RECONDITIONED
FISHERS, 86/88 WELLINGTON ST., WOOLWICH, S.E.18 'PHONE 1055

EAGLE

Offer
C.47 (A)
and
C.47 (B)
DAKOTA
FREIGHTERS
and
PASSENGER
AIRCRAFT

PROPELLERS
INSTRUMENTS
ENGINES — RADIO

Zero time since overhaul.

12 Months' C. of A.

PRATT & WHITNEY
1830-90D ENGINES
IMMEDIATE DELIVERY

Aircraft available for inspection at Blackbushe Airport (By arrangement)

Further details on request to:

EAGLE AIRCRAFT SERVICES LIMITED
A Company of the Eagle Group
BLACKBUSHE AIRPORT
CAMBERLEY, SURREY
Telephone: YATELEY 2371 (P.B.X.)

London office:
29 CLARGES STREET, W.1
Telephone: GROsvenor 6411

AIRCRAFT WANTED

W. S. SHACKLETON, LTD.

wish to purchase

RAPIDES

AUTOCRATS

GEMINIS

MESSENGERS

OFFERS to W. S. Shackleton, Ltd., at 175 Piccadilly, London, W.1. HYDe Park 2448-9. [0071

OUR demand for good used aircraft of all descriptions is very great. Operators or owners wishing to dispose of aircraft, engines, or anything aeronautical, are asked to communicate at once to:—
R. K. DUNDAS, Ltd., 29 Bury Street, London, S.W.1.
WHI. 2848. Cables: "Dundassaero, Piccy, London."
CROYDON AIRPORT. CRO. 7744. [0558

AIRCRAFT ACCESSORIES AND ENGINES

DAKOTA OPERATORS are invited to send their Pratt & Whitney engine overhauls to AEROSERVICES. A quotation for straight overhaul or overhaul by exchange will be sent on request. Write, telephone or call
AEROSERVICES, LIMITED
CROYDON AIRPORT
Tel.: CROydon 9373. Cables: "Aeroserv, Croydon." [0942

A. J. WALTER
WE were laboriously composing a list of C47 spares for inclusion in this advertisement.
HOWEVER, it occurs to us that nearly all our clients have a C47 parts catalogue and therefore there seems little point in reprinting same in these columns during the next few months.
IF your requirement is for C47 spares, then contact us straight away for you will save both your time and ours.
A. J. WALTER, Gatwick Airport, Horley, Surrey. Tel.: Horley 1420 and 1510, Ext. 105. Cables: "Cubeng, London." [0268

HARLEY landing lamp and fittings for Auster. Good condition. Any reasonable offer accepted.—Anglian Air Charter, Gt. Yarmouth. [1872

LARGE stocks aircraft elec. and radio instruments. British and American.—I.S. (Stratford), Co., 60 New Oxford Street, W.C.1. MUSeum 9115. [1876

BONANZA spares for sale, including propeller blades, undercarriage struts, fuel tank, wing, Continental engine, etc., etc.—Air Couriers Ltd., Croydon Airport, Surrey. [1812

BRITISH and American filaments, landing lamps, fuses, generators, cabin heaters, electrical and radio spares.—Suplex Lamps, Ltd., 239 High Holborn, London, W.C.1. Tel.: HOL. 0225 and 4543. [0433

VENDAIR, Croydon Airport, suppliers of aircraft components, engines and ancillary equipment for British and American aircraft. Vendair, Croydon 5777. [0608

INSTRUMENT and autopilot overhaul, test, sales. Dakota and most other instruments from stock.—Repaircraft, Broadbridge Heath (Tel. 11), Horsham, Sussex. [1873

AIRCRAFT SERVICING

REPAIRS and C. of A. overhaul for all types of aircraft.—Brooklands Aviation, Ltd., Civil Repair Service, Sywell Aerodrome, Northampton. Tel.: Moulton 3218. [0307

CAPACITY AVAILABLE

PRECISION engineers. Personal service for prototypes, small quantity machined parts and equipments to drawings and sketches. A.I.D. approved. Mech. and Elec.—Cathanode, Ltd., Vineyard Walk, Clerkenwell, E.C.1. Tel.: TERminus 5113. [1280

CARAVANS

AT HOME—ON THE JOB

NO need any longer to tolerate exorbitant rents, dictatorial landladies or a family upheaval every time you are posted. In an F.O.C. caravan home you can lead a new life of freedom, comfort and independence at less cost. The caravan you are looking for, new or slightly used, which will delight your family may be amongst the 20 models now on show. Write for your copy of "Happy Homes Unlimited," mentioning this paper.
F.O.C. CARAVAN CENTRE, 200-220 Cricklewood Broadway, London N.W.2. Gladstone 2234. [1867

FIELD'S

A HUNTING GROUP COMPANY
in association with
Clan Line Steamers

PRATT & WHITNEY
1830's
ENGINE
OVERHAUL
SERVICE

COMPLETE OVERHAUL

EXCHANGE

SALE

EARLY DELIVERIES

CONTRACTS OR INDIVIDUAL ENGINES

Full details on application to:—

FIELD AIRCRAFT SERVICES LIMITED
CROYDON AIRPORT
CROYDON · SURREY
Phone: CROydon 7777
Cables: FIELDAIR, Croydon

129/158

Dermatitis, production's greatest enemy, can soon put the best hands out of action. Where industrial irritants — oils and solvents — are being constantly handled, Rozalex is essential. It creates a barrier against dermatitis. There is a type for every trade. Send for free sample and leaflet "The Skin in Industry" to Rozalex Ltd., 10 Norfolk Street, Manchester 2.

ROZALEX

DERMATITIS BARRIER CREAMS

Aero & Jig & Tool Draughtsmen in Great Demand

MEN & YOUTHS

There is an insatiable demand for Aero, Jig and Tools, etc., Draughtsmen and Inspectors.
So acute is the present shortage that employers are only too anxious to engage those with no previous practical experience who are able to prepare neat and accurate drawings.

QUALIFY AT HOME—IN SPARE TIME
After brief, intensely interesting study—undertaken at home in your spare time—YOU can secure an attractive and interesting post as **Aero-Draughtsman.** Numerous vacancies are also available in **Electrical, Mechanical, Plastics,** etc., branches of Draughtsmanship.

FREE GUIDE

The Free Guide contains 132 pages of information of the greatest importance to those seeking such success compelling qualifications as **A.M.I.Mech.E., A.F.R.Ae.S., A.M.I.P.E., A.M.I.M.T., Gen. Cert. of Educ.,** and **B.Sc.,** etc., also **R.A.F. Entry** (Maths., etc.), together with particulars of our remarkable guarantee of

SUCCESS—OR NO FEE

Write now for your copy of this remarkable publication. It may well prove to be the turning point in your career.

NATIONAL INSTITUTE OF ENGINEERING

(Dept. 427), 148-150, HOLBORN, E.C.1
(South Africa: E.C.S.A., P.O. Box 8417, Johannesburg).

CLOTHING

R.A.F. and R.N. officers' uniforms purchased; large selection of R.A.F. officers' kits for sale, new and reconditioned.—Fisher's, Service Outfitters, 85-88 Wellington St., Woolwich. Tel.: Woolwich 1055. [0567

CLUBS

LONDONERS! Your most accessible and reasonable club. M.C.A. approved courses. Austers 45/- hour, trial lesson 17/6. Phone Penguin Flying Club, Vic. 1300. [0285

HERTS and ESSEX AERO CLUB, Broxbourne Aerodrome, Nazeing, Essex. M.C.A. approved 30-hour course; residential; trial lessons, 35/-; train from Liverpool Street, or Green Line Coach 715. Tel.: Hoddesdon 2453, 2421. [0230

PLYMOUTH AND DISTRICT AERO CLUB for Auster and Tiger Moth flying instruction; dual and solo at £3 per hour reducing to less than £2 per hour for solo flying on "Fly Yourself Hire" basis; flying instructor's courses and M.C.A. approved course for private pilot's licence.—Tel.: Plymouth 72753. [0341

CONSULTANTS

R. W. SUTTON (CONSULTANTS), Ltd., 7 Lansdown Place, Cheltenham. Tel. 5811. [0291

GROUP CAPT. E. L. MOLE, B.Sc., A.F.R.Ae.S., 31 Dover St., London, W.1. Grov. 5902. [0400

WING COMMANDER R. H. STOCKEN, F.R.Ae.S., Eagle House, 109 Jermyn St., London, S.W.1. Tel.: Whitehall 8863. [0419

R. J. DUNDAS, Ltd., have been giving the correct answer to aviation problems for twenty years. Technical. Purchasing. Operations. Marketing. 20 Bury Street, London, S.W.1. WHI. 2848. [0569

CONTACT LENSES

MODERN Contact Lens Centre, 7(D1), Endsleigh Court, W.C.1. Deferred terms. Booklet sent. [0342

FINANCIAL PARTNERSHIPS, ETC.

TECHNICIAN with 20 years D.O., stress and aerodynamics experience wishes to contact others interested in forming design group. Small capital essential.—Box 4555. [1871

MISCELLANEOUS

HOLE gauge by Federal, U.S.A., for sale. Model portable 1201.P/4. Gauging length 12in., range 4-10in. dia. Perfectly new, in original box.—Box 4513. [1864

PHOTOGRAPHY

FAIRCHILD cameras K24, K20, K19, K8A-B, brand new.—E.W.S. Co., 69 Church Road, Moseley, Birmingham. [1752

PUBLIC ANNOUNCEMENTS

AIR TRANSPORT ADVISORY COUNCIL

THE Air Transport Advisory Council give notice that they have received the undermentioned application to operate a scheduled air service:

APPLICATION No. 4/3 from East Anglian Flying Services, Ltd., of Southend Airport, Southend-on-Sea, Essex, for permission to operate DH89, Avro Anson, Marathon, Dakota and/or DH Heron aircraft on their normal scheduled services on the routes Ipswich-Southend-Rochester-Shoreham-Alderney-Guernsey-Jersey (Application No. 4), Ipswich-Southend-Ostend (Application No. 5), Ipswich-Southend-Rochester-Shoreham-Paris (Application No. 6), Ipswich-Southend-Calais (Application No. 207), and on the sector Portsmouth-Shoreham (Application No. 102), which have already been approved by the Minister of Transport and Civil Aviation.

APPLICATION No. 287 from Fairways, Jersey, of Midland Bank Chambers, Mulcaster Street, St. Helier, Jersey, C.I., for an internal service with Avro XIX aircraft and later with Dakota aircraft, for the carriage of passengers, supplementary freight and mail between Blackbushe and Guernsey and Jersey for a seven-year period from May 1st, 1954, at a frequency of from two to 30 return flights weekly during the season May to September inclusive.

THESE applications will be considered by the Council under the terms of reference issued to them by the Minister of Civil Aviation on July 30th, 1952. Any representations or objections with regard to this application must be made in writing, stating the reasons, and must reach the Council within 14 days of the date of this advertisement, addressed to the Secretary, Air Transport Advisory Council, 9 Buckingham Gate, London, S.W.1, from whom further details of the application may be obtained. When an objection is made to an application by another air transport company on the grounds that they are applying to operate the route or part of route in question, their application, if not already submitted to the Council, should reach them within the period allowed for the making of representations or objections. [1878

The New 1954 'FLIGHT LIEUTENANT' HANDLESS WATCH

No Glass, No Dial, No Hands
Built for strength, fitted with aircraft shock-resisting movement. Lever escapement. Anti-magnetic and recoil click spring to prevent over-winding. Encased handsome chrome case. Expanding bracelet 10/6 extra if required. Time shown by revolving figures. Sent for 5/- dep. Bal. 10/- monthly. Non-luminous. Night dial 6/6 extra. Mfrs. Full Guar. Cash price 79/6 Post, etc., 1/3.

Free Illustrated Lists of other Watches, Binoculars, Tents, Suiting Patterns, Radios, etc. Terms. State lists required.

HEADQUARTER & GENERAL SUPPLIES LTD.
(Dept. FLI 24), 196-200 Coldharbour Lane, Loughborough Junction, London, S.E.5.
Open all Saturday. 1 p.m. Wednesday

Undercarriages—complete
Wheels—complete
De-Icer Boots
Axles,
etc.

DAKOTA SPARES

In fact everything you are in need of!
And all for immediate delivery ex stock

Staravia
BLACKBUSHE AIRPORT
CAMBERLEY, SURREY
Tel.: Camberley 1600

Machinists of plastics for the Aircraft Industry
A.I.D. & A.R.B. APPROVED
Fairleads, Cleats, Panels, Knobs, etc.
E. S. ASTON & CO. LTD.
4 SEBASTIAN STREET
CLERKENWELL, LONDON, E.C.1
Telephone: CLERKENWELL 2179

The . . .
British Air Line Pilots' Association
95 MOUNT STREET, W.1
Tel.: GROsvenor 6261

Membership open to all Commercial and Service pilots. For full details as to the objects and particulars of Membership please write to Secretary.

AIRCRAFT SPRING WASHERS

TO B.S. SPECIFICATION S.P.47

CROSS MFG. CO. (1938) LTD., COMBE DOWN, BATH

CENTRIFUGAL CASTINGS
in Aluminium Bronze, Manganese Bronze, Phosphor Bronze, Gunmetal and Monel Metal.
Proof Machined
AID and Admiralty Approved
WHYTE & COLLINS LTD.,
Kelvin Works Fenton Stoke-on-Trent
Telephone: Stoke-on-Trent 48107

STANDARD AIRCRAFT PARTS

CURD COMPONENTS LTD.
41, LONSDALE ROAD, LONDON, W.11.

GLIDING TUITION

HOLIDAY gliding courses with the Bristol Gliding Club. Ab initio instructions in dual control 2-seater gliders. 12½ gns. for week's course including accommodation.—Full details, Hon. Course Secretary, 12 Wyck Beck Road, Brentry, Bristol. [1826

OBITUARY

ALLARDYCE. On Friday, March 26th, in Hertford General Hospital, after a short illness, William Lumsden Allardyce, the beloved husband of Lucy, of 27 Ellenbrook Lane, Hatfield. [1861

PACKING AND SHIPPING

R. AND J. PARK, Ltd., 143-9 Fenchurch St., E.C. Tel.: Mansion House 3083. Official packers and shippers to the aircraft industry. [0012

EXPORT PACKING SERVICE, Ltd., Imperial Buildings, 56 Kingsway, W.C.2. Phone: Chancery 5121-2-3. Scientific packers to the Services and industry. Specialists in the packing of aircraft and aircraft components. Approved packers for the Admiralty, A.I.D., I.F.V., C.I.A., C.I.S., I.E.M.S., M.o.S. and many foreign Government Departments. [0920

TUITION

THE COLLEGE OF AERONAUTICS

APPLICATIONS are invited for the Perring Scholarship in Aeronautics, valued £400 per annum, tenable at the College of Aeronautics. The successful candidate will be admitted to the two-year course at the college.

APPLICANTS should preferably be honours graduates or final-year undergraduates in engineering, mathematics or physics; applications from non-graduates with comparable qualifications will also be considered. Candidates must be British subjects domiciled in the United Kingdom.

FORMS of application and statement of conditions will be forwarded on written application to The Warden, The College of Aeronautics, Cranfield, Bletchley, Berks.

THE closing date for the receipt of applications is 1 June, 1954. [1760

THE COLLEGE OF AERONAUTICS

English Electric Research Fellowship in Aeronautics

APPLICATIONS are invited for a research fellowship which has been established at the College by the English Electric Co., Ltd. The fellowship is intended to provide opportunity for post-graduate research into problems of vibration or stability and control of aircraft, and is tenable for one year beginning on or about 1 October, 1954. The value of the fellowship is £500.

APPLICATIONS, giving full particulars of education and experience and quoting the names of three referees, are required by 1 May, 1954, and should be addressed to: The Warden, The College of Aeronautics, Cranfield, Bletchley, Bucks. [1761

AVIGATION Limited

30 CENTRAL CHAMBERS, EALING, W.5
(Tel.: EALing 8949)

WE offer all courses appertaining to pilot/navigator licences. Multicolour lithograph presentation of lecture precis to I.C.A.O. standards.

LINK training dept. situated centrally in London. Full briefing for instrument rating 25/- per hour. Block rate, 10 hours, reduces to 22/6. [0248

NIGHT FLYING

INSTRUMENT RATING

TWIN CONVERSIONS

EVERY facility at reasonable rates from:—

SOUTHEND-ON-SEA MUNICIPAL AIR CENTRE and FLYING SCHOOL, Municipal Airport, Southend-on-Sea. Rochford 56204. [0452

LONDON SCHOOL OF AIR NAVIGATION

OFFERS facilities for establishing oneself in a career. Keynote of success is our combined experience with personal approach.

ALL aspects of pilot/navigator qualifications. Our individual coaching methods lead to a very high degree of pass.

NEW "Home Study" courses excellent alternative. Full coverage; unique application; finest of kind, modern diagrammatic presentation.

LINK, briefing, procedures and R/T. instrument flying and refresher. Type ratings—general and specific.

ALL requirements rehabilitation from Services, advice without obligation.

33 Ovington Square, Knightsbridge, London, S.W.3. KEN. 8221. [0277

LEARN to fly for £24; instructors' licences and instrument flying for £3 per hour; night flying £4 per hour; residence 5 gns. weekly. Approved M.C.A. private pilot's licence course.—Wiltshire School of Flying, Ltd., Thruxton Aerodrome, Andover, Hants. [0253

CANADAIR

LIMITED • MONTREAL

OFFERS OPPORTUNITIES TO

ENGINEERS
DESIGNERS
DRAUGHTSMEN

Positions are available for employment on long term design and development projects in the following fields:

AERODYNAMICS
(4 YEARS MINIMUM EXPERIENCE)

and

STRESS ANALYSIS
STRUCTURAL TEST
DYNAMICS
AIRFRAME DESIGN
MECHANICAL DESIGN
ELECTRICAL DESIGN

and

ARMAMENT, RADIO, RADAR & EQUIPMENT INSTALLATIONS DESIGN

Excellent opportunities for advancement in an expanding organization.

★ FIVE DAY WEEK
★ RETIREMENT PENSION PLAN
★ GROUP INSURANCE BENEFITS

SUCCESSFUL APPLICANTS WILL RECEIVE GENEROUS MOVING ALLOWANCES

Application forms may be obtained from the following address and should be returned not later than April 30th. Arrangements will be made for interview in England during May.

Apply to:

J. H. DAVIS
European Representative
of
CANADAIR LIMITED
c/o Canadian Dept. of Labour,
61 GREEN STREET, LONDON, W.1

TUITION

FREE! Brochure giving details of courses in all branches aero eng. covering A.F.R.Ae.S., A.R.B. Certs., M.C.A. exams, etc. We are the only postal training college operated by an industrial organization. —Write to E.M.I. Institutes, Postal Division, Dept. F26, 43 Grove Park Road, London W.4. [0964

BRITAIN'S AIR UNIVERSITY CAN TRAIN YOU for an airline career. Hundreds of today's airline captains and key maintenance personnel are graduates of this famous establishment. Courses are available for Commercial and Airline Transport Pilots' Licences, Instrument rating and Maintenance Engineers' Licences.

FOR details of these and other courses, apply to—The Commandant, Air Service Training, Ltd., Hamble, Southampton. [0970

A.F.R.Ae.S., A.R.B.Certs., A.M.I.Mech.E., etc., on "no pass no fee" terms; over 95 per cent. successes. For details of exams and courses in all branches of aeronautical work, navigation, mechanical eng., write for 144-page handbook, free.—B.I.E.T. (Dept. 702), 29 Wright's Lane, London, W.8. [0707

AERONAUTICAL. Comprehensive full-time technical and practical training for careers in all branches of aviation engineering. Diploma course leads to interesting executive appointments in civil aviation design and development, draughtsmanship, maintenance, etc. Extended courses to prepare for A.F.R.Ae.S. and A.M.I.Mech.E. examinations.—Write for prospectus to Senior Master, College of Aeronautical Engineering, Chelsea, London, S.W.3. Flaxman 0021. [0019

SITUATIONS VACANT

The engagement of persons answering these advertisements must be made through the local office of the Ministry of Labour and National Service, etc., if the applicant is a man aged 18-64 or a woman aged 18-59 inclusive, unless he or she or the employer is excepted from the provisions of The Notification of Vacancies Order 1952.

THE SUPERMARINE WORKS OF VICKERS-ARMSTRONGS, LIMITED

NOW IN PRODUCTION OF SUPER-PRIORITY AIRCRAFT, REQUIRE:

TECHNICAL ASSISTANTS

for structural analysis and structural testing. Qualification, degree or H.N.C. Previous experience of this work not essential.

AERODYNAMICISTS

Qualification: degree or equivalent standard. Some experience in aeronautical engineering desirable.

DESIGN DRAUGHTSMEN
(Senior and Junior)

Preferably with aircraft experience, but men with mechanical, structural or electrical experience also considered. Requirements are mainly for airframe design, but certain vacancies exist for work on wind tunnel models and equipment, and on aircraft instrumentation.

FULL-SCALE LAYOUT DRAUGHTSMEN
(Senior and Junior)

Preferably with aircraft experience.

JIG AND TOOL DRAUGHTSMEN

For designing machine fixtures, assembly tools and jigs.

Write, giving full particulars, including age and salary required, to Personnel Department, Hursley Park, near Winchester, Hants. [1801

AERODYNAMICISTS

A RAPIDLY expanding precision instrument manufacturing firm holding long-term design and development contracts has the following vacancies:

(a) Senior aerodynamicist with experience of dynamic stability analysis in connection with the design and development work of autopilots. Knowledge of servo mechanisms an advantage. Position offers exceptional opportunity for the right man. Ref. S.E./2.

(b) Young graduates and personnel with equivalent professional qualifications for training in the above field. Ref. G.E./2.

PLEASE forward full details of career and salary required (which will be treated in strict confidence), quoting appropriate reference, to Box 4582. [1883

THE UNIVERSITY OF SOUTHAMPTON

Department of Aeronautical Engineering

A VACANCY has occurred for a research student in the Department of Aeronautical Engineering to carry out research on turbulence, noise and high-speed flow problems. Facilities for pursuing a post-graduate degree are available in this post. Some experience in aeronautics is preferable, but not essential. The applicant selected will receive a research grant in the range of £400-£500 per annum.—Further particulars can be obtained from the Professor of Aeronautical Engineering, The University, Southampton. [1870

SITUATIONS VACANT

Expanding

Gas Turbine Activities

of

D. NAPIER & SON, LTD.

demand the appointment of

ENGINEERS

both junior and senior, for design, development, research, production and testing.

APPLICATIONS from men with experience in any of the following will be particularly welcome:—

Weight Control
Stress Calculation
Forward Project Design
Blade Design
Control Systems
Full-scale Engine Design
Engine Test Administration
Performance Analysis and Report Writing
Vibration Investigation
Failure Investigation
Engine Build Specification Research
Jig and Tool Design
(only senior positions)
Planning
New Process Development
(particularly sheet metal fabrication)
Test Plant Design

Applications should be addressed to:—
CENTRAL PERSONNEL SERVICES
336-7 Strand, W.C.2.
Quoting reference S.A.30F. [1866

BLACKBURN AND GENERAL AIRCRAFT, LTD.

have vacancies in the

ELECTRONICS SECTION AT BROUGH

FOR one senior and two junior technicians for work on strain-gauging, electronic instrumentation, and vibration investigation on aircraft and gas turbines. Previous experience of this type of work essential for senior grade and desirable for junior grade.

THE company's programme on military and civil aircraft offers excellent prospects of permanent and interesting work under congenial conditions at salaries commensurate with qualifications, ability and experience.

APPLICATIONS, giving full particulars of age, training, etc., to:—
THE PERSONNEL MANAGER,
BLACKBURN AND GENERAL AIRCRAFT LTD.
Brough, Yorks. [1774

THE UNIVERSITY OF SOUTHAMPTON

Department of Aeronautical Engineering

APPLICATIONS are invited for the post of lecturer in aeronautics to specialise in the teaching of undergraduate and post-graduate students in high-speed flow problems. Some experience in this field is desirable though not essential. In the absence of a suitable candidate, a lecturer specialising in aircraft structures and aero elasticity would be considered.

THE post will be tenable from October 1st, 1954, or as soon as possible thereafter.

SALARY scale: £550 by £50 to £1,100, plus F.S.S.U. and children's allowances.—Further particulars may be obtained from the Secretary and Registrar, The University, Southampton. [1869

AERONAUTICAL RADIO ENGINEERS

MARCONI'S WIRELESS TELEGRAPH Co., Ltd., are continually expanding their already wide activities in the field of aeronautical radio. There are posts available for development, project, field and sales engineers on all aspects of airborne and ground communications and radio and radar navigational aids for both civil and military purposes. Any engineer who is interested in this field should apply, in confidence, giving details of his experience, etc., and quoting reference S.A.44, to: The Manager, Aeronautical Division, Marconi's Wireless Telegraph Co., Ltd., Dept. C.P.S., 336-7 Strand, W.C.2. [1860

WILMOT BREEDEN, LIMITED

CAMDEN STREET, BIRMINGHAM, 1

ESTIMATING ENGINEER

REQUIRED for estimating production costs of aircraft components in stainless steel and light alloys. Essential experience sheet metal work, machining and assembly.

SALARY according to experience and qualifications; monthly staff status; pension scheme.

APPLICATIONS, in writing, to T. C. Wareham, Personnel Manager. [1879

FLYING instructor required by club. Home Counties. C.P.L. an advantage.—Box 4568. [1877

THE ENGLISH ELECTRIC CO. LTD.

(AIRCRAFT DIVISION)

RESEARCH AND EXPERIMENTAL STAFF

Opportunities exist for work in Departments equipped with the latest test and computing machines, and for specializing in one or more of the following fields:—

STRUCTURAL TESTING
HYDRAULIC SYSTEMS
SERVO-MECHANISMS
FUEL AND AIR SYSTEMS
NEW METHODS OF CONSTRUCTION
STRUCTURAL ANALYSIS
FLIGHT TESTING TECHNIQUES
FLIGHT TEST INSTRUMENTATION
AERODYNAMICS
SIMULATORS
FLUTTER AND VIBRATIONS

QUALIFICATIONS:

Engineering Degree or H.N.C. Although aircraft experience essential for certain posts, a sound engineering training is suitable for others. All applicants will be considered on their merits and advised on the most suitable post available.

Laboratories and offices are sited on north-west coast near pleasant residential area.

Apply to
Dept. C.P.S.,
336/7, STRAND, W.C.2.
Quoting Ref. S.A.27.

SITUATIONS VACANT

AIRCRAFT ELECTRICAL INSTALLATIONS

VACANCY occurs in installations section of design department for a young man, preferably electrical engineering graduate, but with at least H.N.C., with practical grounding in electronics and some drawing experience. Duties will include appraisal of special component designs, development of suitable test gear and circuitry, defect investigation on components and laboratory testing.—Detailed applications to Personnel Supervisor, Hawker Aircraft, Ltd., Canbury Park Road, Kingston-on-Thames, Surrey. [1884

HANDLEY PAGE, Ltd., have vacancies at their Radlett laboratories for:

(a) Senior technical assistants for work on structural and mechanical testing. Applicants should possess a degree or H.N.C. and should have some previous experience.

(b) Junior technical assistants for work on structural and mechanical testing and the development of aircraft systems. Applicants should possess a H.N.C. Previous experience is desirable but not essential.

WRITE, stating age and full details, to Staff Officer, Handley Page, Ltd., Cricklewood, London, N.W.2. [1855

THE DE HAVILLAND AERONAUTICAL TECHNICAL SCHOOL, Christchurch, invite applications for the position of sheet metal work instructor.

APPLICANTS should be thoroughly familiar with all types of aircraft sheet metal work and capable of instructing in geometrical development drawing, treatments, and specifications.

PREFERENCE will be given to those possessing Final City and Guilds Certificate, or having previous teaching experience in a similar capacity. [1865

MISSILE engineers required. Ground-floor opportunities are open in a Canadian programme for the following:—

SENIOR systems engineer. Bachelor of Science or better. Six years' experience in missiles or aircraft. Must be able to deal intelligently with correlation of airframe control, aerodynamics, electronics and propulsion systems. Design aptitude important.

SENIOR electronics engineer. Bachelor of Science or better. Six years' experience in missile electronics or related fields. Technical ability in micro-wave spectrum field and in radar. Must have ability to meet people.

SENIOR performance engineer. Bachelor of Science or better. Six years' experience in supersonic aerodynamics or control theory and application. Mathematics aptitude essential.—Box 4581. [1889

THE BRISTOL AEROPLANE Co., Ltd., has a vacancy in the technical publications department of the aircraft division for an experienced airframe spares schedule compiler.

SALARY, pension, working conditions and prospects of promotion on merit are excellent.

APPLICATIONS giving details of experience and qualifications, quoting D.O.14, should be addressed to the Personnel Manager, The Bristol Aeroplane Co., Ltd., Aircraft Division, Filton House, Bristol. [1882

AIRCRAFT radio maintenance engineers (experienced) required.—Applications, giving full particulars, to: Chief Clerk, The College of Aeronautics, Cranfield, Bletchley, Bucks. [1863

SENIOR stressmen required for interesting programme of project and development work.—Applications, stating age, experience and qualifications, should be addressed to Chief Engineer, Folland Aircraft, Ltd., Hamble, Hants. [1875

TECHNICAL representative required by progressive engineering company with large toolroom and production shop. Contacts with aircraft manufacturers essential. Good position for man with energy and initiative. State experience, age and salary.—Box 4062. [1881

WANTED, experienced engine fitter to take charge aero engine overhaul shop on South Coast. Must be good timekeeper and disciplinarian. Sound knowledge of engine overhaul work essential. Firm approved and established.—Box 4403. [1825

SKILLED aircraft tool inspectors required by large factory in Blackpool. Good prospects for experienced men.—Apply, stating age and particulars of experience, to Personnel Officer, Hawker Aircraft (Blackpool), Ltd., South Shore, Blackpool. [1886

SENIOR electrical draughtsmen required to work on super priority aircraft. Considerable experience in latest types of aircraft electrical installations. Pension scheme available.—Apply, with full details, to the Personnel Manager, The Fairey Aviation Co., Ltd., Hayes, Middx, quoting reference ED/1. [1888

AIRCRAFT detail and assembly inspectors with recent experience required for large factory in Blackpool. Good pay and prospects for suitable men. —Apply, stating age and particulars of experience, to Personnel Officer, Hawker Aircraft (Blackpool), Ltd., South Shore, Blackpool. [1885

LEADING manufacturers of aircraft batteries require technical sales representative, age 30-35. Knowledge of aircraft industry and/or service with R.A.F. essential. Previous battery selling experience not important. Successful applicant expected to live London area.—Box 4297. [1891

AIR FORCE, Naval, civil and helicopter aircraft all under design and development at Percival Aircraft, Ltd., Luton Airport, Beds. Applications are invited from senior and junior draughtsmen and stressmen for work on this interesting programme. Good welfare facilities, including staff pension scheme.—Write, giving details of experience and salary required, to Personnel Manager. [0595

SITUATIONS VACANT

SENIOR and intermediate design draughtsmen, with good experience of aircraft or light structural or mechanical engineering, required for aircraft and armament project work.—Apply, by letter, to Portsmouth Aviation, Ltd., The Airport, Portsmouth. [0612

JIG and tool draughtsman (senior) required. Good welfare facilities including staff pension scheme.—Applications, in writing, to Personnel Manager, Percival Aircraft, Ltd., Luton Airport, Beds, stating age, experience and salary required. [0593

TECHNICAL illustrators (male, senior) required. Considerable practical experience of illustrating for sales brochures and descriptive manuals essential. Good welfare facilities including staff pension scheme.—Applications, in writing, to Personnel Manager, Percival Aircraft, Ltd., Luton Airport, Beds, stating age, experience and salary required. [0592

H. M. HOBSON, Ltd., invite applications for positions in the drawing office as follows: designers, detail and modification draughtsmen, checkers, stressmen. The work is concerned with interesting projects connected with fuel metering equipment and hydraulic flying controls for aircraft.—Hobson Works, Fordhouses, Wolverhampton. [0420

TEST laboratory assistants (male) required by Percival Aircraft, Ltd., Luton Airport, Beds. National Certificate standard and previous experience on design of test laboratory equipment desirable. Good welfare facilities including staff pension scheme.—Applications, stating qualifications, experience, age and salary required to Personnel Manager. [0596

THE ENGLISH ELECTRIC Co., Ltd., Luton, have vacancies for technical assistants of H.N.C. standard to carry out development structural tests as part of a comprehensive programme of testing on guided weapons. Previous experience of structural development or aircraft stressing an advantage.—Write to Dept. C.P.S., 336-7 Strand W.C.2, quoting ref. no. 1147F. [1858

SENIOR, intermediate and junior draughtsmen required for aircraft work of super priority. A.E.S.D. rates and upwards, depending on ability. Aircraft experience desirable but not essential. Apply giving age and details of experience and salary required to Personnel Manager, Helliwells, Ltd., The Airport, Walsall. [1821

MECHANICAL engineering detail draughtsman required for work on small aircraft components. Applicants should have good technical training to ordinary national standard, or equivalent. Capable of working with minimum supervision.—Write, giving particulars of age, experience and salary required, to King Aircraft Corporation, Fifth Street, Montrose Ave., Hillington, Glasgow S.W.2. [1862

INSTRUMENT fitter required for strip and re-build of air-driven gyro instruments. All round knowledge of aircraft instruments desirable. Preference given to "X" licence ground engineer. Suitable candidate will be considered for working chargehand of instrument overhaul laboratory.—Apply, in first instance, by letter, to: Managing Director, Wynstruments Ltd., Staverton Aerodrome, Gloucester. [1859

INTEGRAL, Ltd., Birmingham Road, Wolverhampton, invite applications for a vacancy on their design and development staff for work on interesting new projects including aircraft hydraulic mechanisms. Experience of aircraft component designs, testing and good technical qualifications essential.—Applicants please state age, qualifications, experience and salary required. [1857

DEVELOPMENT engineers required for interesting work on the development and testing of new methods of aircraft and helicopter construction and materials. Candidates should have a university degree, Higher National Certificate or equivalent, but equally important are a broad outlook, a practical approach to engineering problems, initiative and enthusiasm. London area.

APPLICATIONS, stating age, qualifications, experience and salary required, should be addressed to Box 4583, quoting reference DE/5. [1887

CHIEF stressman required by Percival Aircraft, Ltd., Luton Airport, Beds, for work on civil and military prototype and production aircraft. Must be capable of taking full responsibility for all stressing and stress office organization.—Applications, in writing, should be made to the Chief Designer, stating age, salary required, full details of training, experience and qualifications. Pension scheme and assistance on housing available. [1880

WAYMOUTH GAUGES AND INSTRUMENTS, Ltd., a subsidiary company of Smiths Aircraft Instruments, Ltd., have vacancies in their engineering department for electrical and mechanical draughtsmen for work on aircraft instruments and electronic equipment. A knowledge of inter-service regulations would be an advantage, but is not essential.—Apply, in writing, to the Chief Development Engineer, Waymouth Gauges and Instruments, Ltd., Station Road, Godalming. [1824

SENIOR weights engineer required. Minimum three years' experience; O.N.C. with experience of project design work preferable. Good welfare facilities, including staff pension scheme.—Applications in writing to Personnel Manager, Percival Aircraft Ltd., The Airport, Luton, Beds., stating age, salary required, experience and qualifications. [1841

HANDLEY PAGE (Reading), Ltd., The Aerodrome, Woodley, Reading, have immediate vacancy for a senior aircraft electrical draughtsman for work on an interesting new project. Only those who are fully experienced in all aspects of the work should apply, and for the successful applicant there will be suitable housing accommodation provided.—Please send full particulars of experience, etc., to the Personnel Officer. [0235

HANDLEY PAGE (Reading), Ltd., The Aerodrome, Woodley, Reading, have vacancies in their design office for senior and intermediate stressmen and weightsmen and for draughtsmen of all grades. The work is on an interesting new project and there will be scope for rapid advancement to suitable applicants.—Please send full particulars of experience, etc., to the Personnel Officer. [0236

ARMSTRONG SIDDELEY MOTORS, Coventry, have vacancies for a number of designers and senior and junior draughtsmen. Although gas turbine experience is most advantageous it is not necessarily essential as training will be given in this specialized work to suitably qualified draughtsmen.—Apply in detail to Reference F.103, Personnel Manager, Armstrong Siddeley Motors, Coventry. [0200

ASSISTANT chief draughtsman. First-class man required, with wide experience, for production drawing office, dealing with the design of automobile and aircraft accessories. Knowledge of light presswork, diecastings, mouldings and small mechanisms desirable. Applicants must be capable of negotiating design features with customers and co-ordinating design with production personnel. This is a responsible progressive position carrying an adequate salary and monthly staff status. Pension scheme.—Applications, stating full details, experience and qualifications, to T. C. Wareham, Personnel Manager, Wilmot-Breeden Ltd., Amington Road, Birmingham 25. [1868

AN attractive appointment in the London area is available for a senior engineer on the mechanical development of an interesting new aero-engine project. Applicants should preferably be between 30 and 40, with a good technical background (e.g. corporate membership of I.Mech.E. or R.Ae.S.) and must have considerable prior experience on the planning and execution of practical development programmes in a comparable field. This need not necessarily be aeronautical, e.g., a background on internal combustion engines of any type, steam turbines, pumps, or other high-class mechanical or hydraulic machinery, would be suitable. Excellent salary to the right man.—Apply to the Chief Engineer, The de Havilland Engine Co., Ltd., Stag Lane, Edgware, Middlesex. [1837

FOR SALE

CIRRUS MAJOR III
2 OFF at **£275** each

CHEETAH XIX
2 OFF at **£250** each

GIPSY SIX I
2 OFF at **£200** each

All the above Nil Hour since complete overhaul. High Mod. Standard.

Box No. 4402 c/o FLIGHT

SILVER CITY AIRWAYS
LIMITED

Opportunities exist at Blackbushe and Lympne Airports for Skilled Aeronautical Engineers to work on Fleet Aircraft in the following categories:—

Licensed Engineers—Engines
Skilled Fitters—Engines
Licensed Engineers—Airframe
Skilled Fitters—Airframe
Skilled Mechanics—Radio
Skilled Mechanics—Electrical
Skilled Mechanics—Instrument

Write for application forms and appointment to:—

Engineering Superintendent,
BLACKBUSHE AIRPORT,
CAMBERLEY, SURREY.

SITUATIONS WANTED

AXED chief instructor reserve school, 34, ex-Halton commercial. Do anything airborne/chairborne.—Box 4567. [1874

EX R.A.F. pilot, 3,600 hrs multi, seeks employment. Anything, anywhere considered. No licences.—Box 4591. [1890

BOOKS, ETC.

"TELEVISION Explained," by W. E. Miller, M.A. (Cantab.), M.Brit.I.R.E. A non-mathematical, simple explanation of television reception circuits. 5th Edition. 5s. net from all booksellers. By post 5s. 4d. from Iliffe & Sons Ltd., Dorset House, Stamford St., London, S.E.1.

Z & I AERO SERVICES LTD.
19 BUCKINGHAM ST., LONDON W.C.2
Tel. TRA 2371/2
For supply of British and American Radio and Aircraft Instruments, Parts, Components and Test Equipment.
WE BUY AMERICAN EQUIPMENT

COTTON BAGS
FOR SPARE PARTS, ETC.
WALTER H. FELTHAM & SON, LTD.
Imperial Works, Tower Bridge Road,
Telephone: HOP 1784 **LONDON, S.E.1**

JET NOISE
Protect your Test-bed and Flight-ramp personnel with

Product of
THE ANTICOUSTIC COMPANY
GUILDFORD, ENGLAND

NOSONIC
EAR DEFENDERS

Sole Suppliers
THE MALLOCK-ARMSTRONG Co.,
204, High Street, Guildford, Surrey
Phone: Guildford 66488

GLOSTER AIRCRAFT CO. LTD.
GLOUCESTER

CAN OFFER EXCELLENT OPPORTUNITIES

TO

DRAUGHTSMEN

aircraft experience not essential

The conditions of employment are good with progressive salary, good sports and welfare facilities, pension scheme, etc.

APPLICATIONS STATING AGE, PREVIOUS EXPERIENCE AND EMPLOYERS SHOULD BE ADDRESSED TO THE **CHIEF DESIGNER**

THE
DE HAVILLAND
AIRCRAFT CO. LTD.
HATFIELD

have vacancies for

DESIGNERS

SENIOR DRAUGHTSMEN

MODIFICATION DRAUGHTSMEN

Preferably with experience in either of the following:

AIRFRAME STRUCTURES

MECHANICAL, ELECTRICAL & RADIO INSTALLATIONS

AIRCRAFT FURNISHINGS

for Civil and Military aircraft.

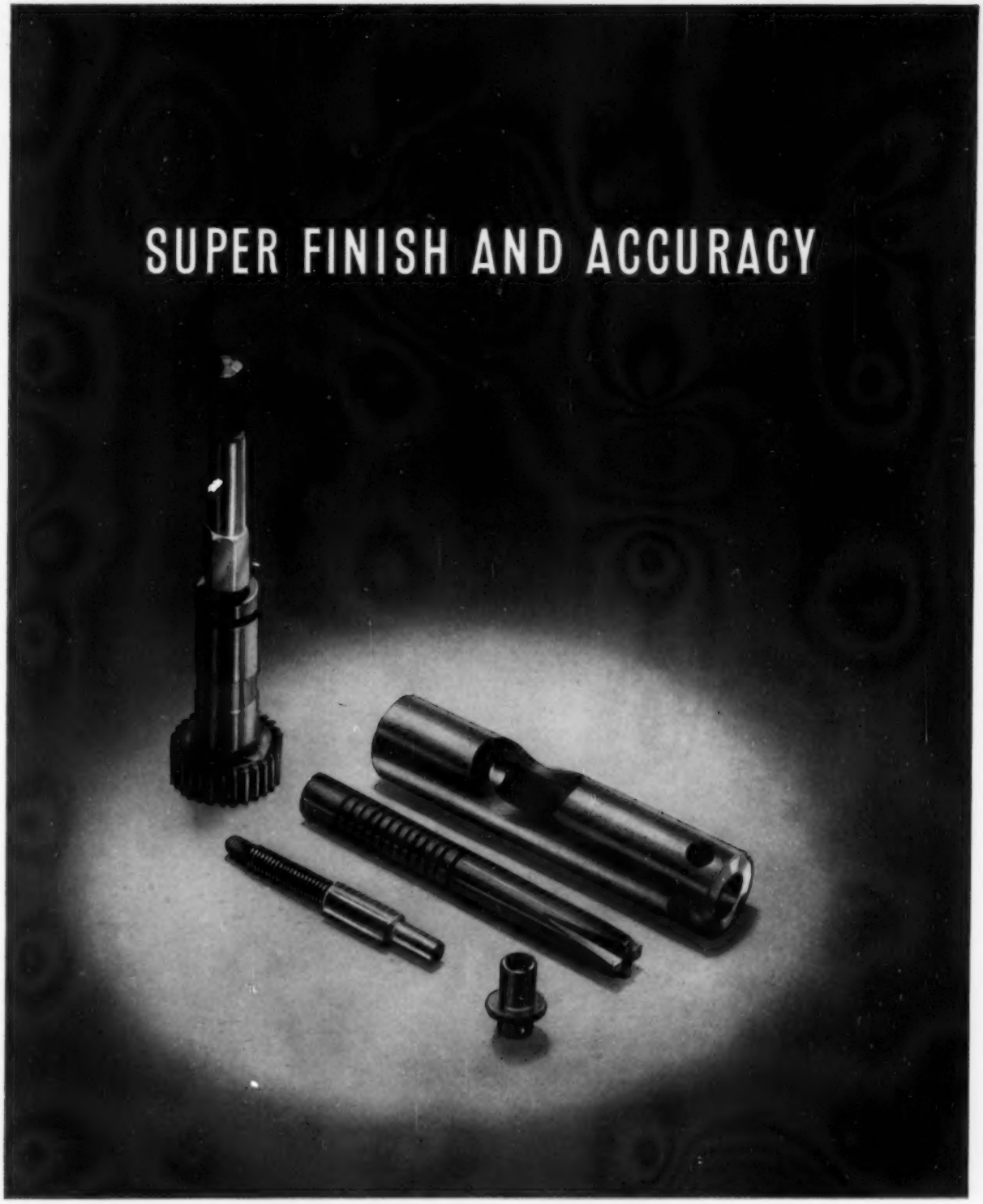
Applications should be addressed to **Chief Draughtsman,**
DE HAVILLAND AIRCRAFT CO. LTD.
Hatfield, Herts.

INDEX TO ADVERTISERS

	Page
Abbey Panel and Sheet Metal Co. Ltd.	9
Aero Research, Ltd.	10
Air Industrial Developments, Ltd.	2
Airwork, Ltd.	62
Alvis, Ltd.	Cover i
Armstrong Siddeley Motors, Ltd.	26
Aston and Co., Ltd., E. S.	64
Auto-Klean Strainers, Ltd.	46
Aviation Developments, Ltd.	12
Aviation Traders (Engineering), Ltd.	18
Avica Equipment, Ltd.	57
Bellman Hangars, Ltd.	54
Blackburn and General Aircraft, Ltd.	22, 23
Boulton Paul Aircraft, Ltd.	5
Bowden (Engineers), Ltd.	14
Box No. 4402	67
Bristol Aeroplane Co., Ltd., The	30, Cover iv
British Air Line Pilots' Association, The	64
British Aviation Insurance Co., Ltd., The	56
British Communications Corporation, Ltd.	50
British Emulsifiers, Ltd.	58
British Insulated Callender's Cables, Ltd.	Cover ii
British Thomson-Houston Co., Ltd., The	61
Burnley Aircraft Products, Ltd.	13
Canadair, Ltd.	43, 65
Carlisle and Co., Ltd., C. G.	59
Cellon, Ltd.	36
Cementation (Muffelite) Ltd.	57
Coley Metals, Ltd.	60
Counting Instruments, Ltd.	52
Cross Manufacturing Co. (1938), Ltd.	62, 64
Curd Components, Ltd.	64
Decca Radar, Ltd.	15
De Havilland Aircraft Co., Ltd., The	68
De Havilland Engine Co., Ltd., The	20
De Havilland Propellers, Ltd.	46
Desoutter Brothers, Ltd.	40
Detuners, Ltd.	44
Eagle Aircraft Services, Ltd.	63
Edison Swan Electric Co., Ltd., The	19
Electro-Hydraulics, Ltd.	16
English Electric Co., Ltd., The	8, 66
Fairey Aviation Co., Ltd., The	25
Feltham and Sons, Ltd., Walter H.	67
Field Aircraft Services, Ltd.	63
Fishers	62
Flight Refuelling, Ltd.	47
Fokker Aircraft	11
Gainsborough Engineering Co. (Oldham), Ltd.	53
General Electric Co., Ltd., The	47
Gloster Aircraft Co., Ltd.	68
Graviner Manufacturing Co., Ltd.	56
Headquarter and General Supplies, Ltd.	64
Hellermann, Ltd.	49
Helliwells, Ltd.	61
Hendrey Relays, Ltd.	49
High Duty Alloys, Ltd.	31
Hordern-Richmond (Sales), Ltd.	54
Hymatic Engineering Co., Ltd., The	6
Iliffe and Sons, Ltd.	50
Jessop, Ltd., William	32
Kigass, Ltd.	3
Lewis, Ltd., D.	62
Leytonstone Jig and Tool Co., Ltd.	52
Lodge Plugs, Ltd.	41
Lucas (Gas Turbine Equipment), Ltd., Joseph	Cover iii
Mallock-Armstrong Co., The	67
Marston Excelsior, Ltd.	48
Martin-Baker Aircraft, Ltd.	27
M.H.H. Engineering Co., Ltd.	58
Napier and Son, Ltd., D.	33
National Institute of Engineering	64
Newton Brothers (Derby), Ltd.	56
Power Jets (Research and Development), Ltd.	12
Powis and Sons, Ltd., David	54
Precision Rubbers, Ltd.	51
Ransome and Marles Bearing Co., Ltd.	45
Riley, Ltd., Robert	60
Roe and Co., Ltd., A. V.	24
Rollet and Co., Ltd., H.	14
Rolls-Royce, Ltd.	35
Rotol, Ltd.	29
Rozalex, Ltd.	64
Salter and Co., Ltd., George	17
Saunders-Roe, Ltd.	28
Scintilla, Ltd.	52
Self-Priming Pump and Engineering Co., Ltd.	21
Shell-Mex and B.P., Ltd.	42
Short Brothers and Harland, Ltd.	55
Siebe, Gorman and Co., Ltd.	50
Silver City Airways, Ltd.	67
Smith-Clayton Forge, Ltd.	37
Staravia	64
Teddington Controls, Ltd.	60
Teleflex Products, Ltd.	4
Terry and Sons, Ltd., Herbert	1
Tungum Co., Ltd., The	48
Unijoints (I.V.) and Co.	58
Vokes, Ltd.	51
Wakefield and Co., Ltd., C. C.	38
Walker and Co., Ltd., James	39
West and Partners, Ltd., A.	53
Westland Aircraft, Ltd.	7
Whyte and Collins, Ltd.	64
Wiggin and Co., Ltd., Henry	34
Z. and I. Aero Services, Ltd.	67
Zwicky, Ltd.	59

Printed in Great Britain for the Publishers, ILIFFE & SONS LTD., Dorset House, Stamford Street, London, S.E.1, by SUN PRINTERS LTD., London, and Watford Herts. *Flight* can be obtained abroad from the following: AUSTRALIA AND NEW ZEALAND: Gordon & Gotch, Ltd. INDIA: A. H. Wheeler & Co. CANADA: The Wm. Dawson Subscription Service, Ltd.; Gordon & Gotch, Ltd. SOUTH AFRICA: Central News Agency, Ltd.; Wm. Dawson & Sons (S.A.), Ltd. UNITED STATES: The International News Co. Entered as Second Class Matter at the New York, U.S.A., Post Office.

SUPER FINISH AND ACCURACY



No. 1. High pressure fuel flow controlled by low torque manual throttle valve using components of high surface finish with an accuracy of twenty-millionths of an inch.

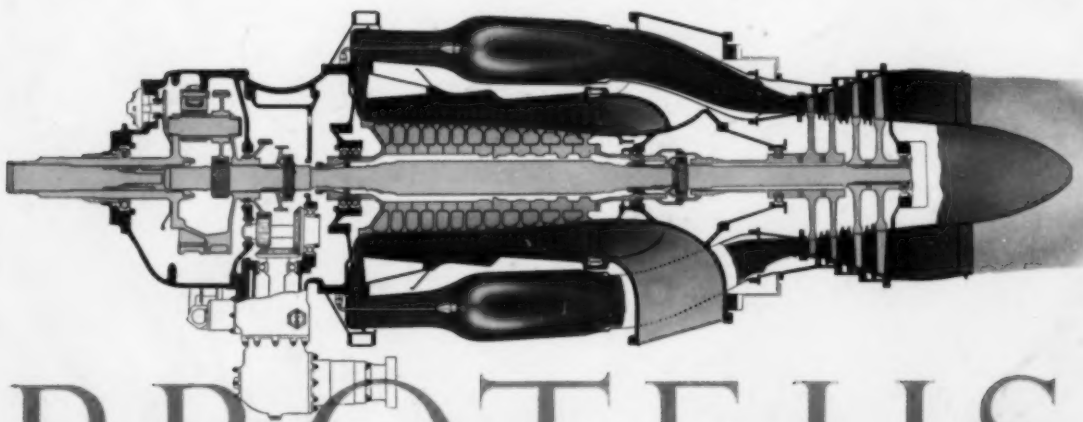
Fuel and Combustion Systems for Gas Turbine Engines

LUCAS

JOSEPH LUCAS (Gas Turbine Equipment) LTD., BIRMINGHAM & BURNLEY

The Free Turbine Engine

The only drive coupling between the propeller and the power-section of a free-turbine engine such as the Proteus is the gas stream. Because of this, starting is easy (the engine can be started with the propeller feathered) and control is much simplified. As they are not mechanically coupled, the propeller and the power section can each operate at their optimum conditions, and thus cruising altitude can be widely varied whilst still maintaining an unusually low specific fuel consumption. In addition, the windmilling drag is scarcely higher than that of a feathered propeller and aircraft control in the asymmetric case is thereby greatly eased.



PROTEUS

THE Bristol AEROPLANE COMPANY LIMITED · ENGLAND